

GAME THEORY AND THE FIRST WORLD WAR

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Abstract: Books by Scott Wolford and Roger Ransom show how economic theories of games and decisions can be fruitfully applied to problems in World War I. This vital application offers fundamental insights into the analytical methods of game theory. Public random variables may be essential factors in war-of-attrition games. An assumption that nations can coordinate on Pareto-superior equilibria may become less tenable when nations are at war. Interpreting a surprising mistake as evidence of an unlikely type can have serious consequences. The ability of leaders to foster consistent beliefs within a cohesive society can create inconsistency of beliefs between nations at war. *JEL codes:* C70, D74, F51.

1. Introduction

To review the history of World War I is to be reminded that leaders of great nations can make disastrous decisions that shatter civilization. Whatever their received wisdom had taught the leaders of 1914 about managing a global political system, it was not enough. A century after its end, their Great War still demands deeper understanding from us, if we are to have any hope of avoiding such disasters in the future. If we had a general conceptual framework that could explain why powerful national leaders made such ruinous choices in the summer of 1914, then perhaps we could face the new challenges of our own time with greater confidence. So when we want to assess the power of economic theory to offer valuable insights into problems of the modern world, a re-examination of fateful decisions in the First World War may be an appropriate place to start.

This approach has been fruitfully probed in two noteworthy recent books. *Gambling on War*, by Roger Ransom (2018), reviews the history of World War I as a series of situations where decision-makers repeatedly manifested a preference for risk-seeking against losses, consistent with common patterns that have been identified in behavioral economics. *The Politics of the First World War*, by Scott Wolford (2019), is a game theory textbook where each chapter introduces a basic concept in game theory and then applies it to help analyze an event in World War I. This approach is particularly rewarding in Wolford's book, where he shows both that game theory can offer valuable insights into the enigmas of World War I, and that World War I is a valuable case for demonstrating how game theory can be applied. Wolford finds more than

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enough interesting applied questions from the history of World War I to be able to introduce each of the most important ideas of game theory in the context of an applied question from the period. In fact, Wolford successfully introduces concepts of game theory in a logical order even while the corresponding applications are considered in a historical order, starting with a pre-war arms race and ending with the 1918 armistice.

The plan of this paper is as follows. Section 2 reviews key points from Ransom's book and considers how some of the observed decision biases might be rationalized, examining particularly the adaptive value of overconfidence as a perceptual bias that can strengthen resolve and cohesion for groups in conflict. Section 3 reviews Wolford's game-theoretic modeling of the causes of World War I, based largely on an analytical framework from James Fearon (1995). Wolford's modeling of the duration of the war is discussed in section 4, where we consider how the basic game-theoretic model of a war of attrition could be modified to better fit some key issues of the war. Then the last three sections consider how our ability to understand the war might be enhanced by relaxing some common assumptions of game-theoretic analysis. Section 5 asks whether problems of international relations should be modeled as games played by nations, or should our models include players that represent various subnational actors. Section 6 reconsiders the basic assumption of rational decision-making and shows how our understanding of the war can be broadened by admitting the possibility of one momentous mistake in August 1914. Section 7 reexamines the basic assumption that players have consistent beliefs and suggests that, like truth, game-theoretic consistency may be among the first casualties of war.

2. A propensity for gambling and groupthink in war

Ransom (2018) approaches the First World War as an economic historian. The war effort in each country depended on vast production of war materials, and the demand to sustain this war production for years was a supreme test of each country's economic development. In this cruel test, the capabilities in Russia and Austria proved to be substantially less than in the other great powers, Germany, Britain, and France. In his section on economies at war, Ransom notes that Russia and Austria had much higher war-time price inflation than the other three major combatants, and government spending as a fraction of national income actually declined during the later war years in Russia and Austria, while this fraction was steadily increasing in Germany, Britain, and France. This difference in economic capacity was a significant determinant of military outcomes in the later years of the war. We may readily attribute this difference to the

less advanced level of economic development in Russia and Austria, compared to Germany, Britain, and France in 1914. But then we should try to understand which specific aspects of economic development made the most difference to the way that these countries performed in the crucible of war.

Ransom remarks that the war economies in Germany, Britain, and France all relied on private production, and the presence of well-developed markets was a key element for successful economic mobilization. But only some aspects of their "well-developed markets" would continue to apply after the massive transition from production of consumer goods to military goods. Presumably the crucial aspects might include those customs and institutions that enabled a broad group of entrepreneurial individuals to form new trade relations with trust and reliability, and those that enabled the government to effectively tax and regulate such private enterprise. Certainly Russia and Austria had significantly less ability to finance their war effort by selling public debt, and this financial constraint may have contributed to the collapse of both empires by the end of the war. But were people less willing to buy Russian and Austrian debt simply because they foresaw the potential collapse of these states, or were deeper structural factors limiting these states' ability to sell public debt? Russia's war effort was also weakened by its limited ability to tax its peasants, as the conversion of Russian industry from consumer goods to military production reduced peasants' incentives to bring their crops to market. When we examine such issues as they became significant in World War I, we find that the war can provide an alternative perspective on the fundamental meaning of economic development.

Ransom's main focus throughout his book is on the prevalence of risk-seeking behavior in major decisions throughout the war, as political leaders and military commanders regularly chose to gamble on warfare rather than pursue options that might have led to peace. Such risk-seeking seems clearly identifiable in the decisions to mobilize forces that could provoke a world war, the decision to launch the vast offensive of the Schlieffen Plan in August 1914, the decisions to continue the war after the failure of the Schlieffen Plan, the decisions to send waves of troops into fruitless offenses from the Somme to Gallipoli, and the decision to launch unrestricted submarine warfare in 1917.

Our problem is to identify what theoretical framework should be used to explain such risk-seeking in war. To be useful, a theory of "animal spirits" must go beyond generalities to say something about when this force applies and when it does not, since people do not always choose to gamble on war. Ransom offers some suggestions of how the condition of being at war could

promote risk-seeking behavior which then drives the continuation of war. Once the war started, the technical complexity of warfare compelled political leaders to leave the decisions of military strategy to generals, but generals who lacked a strong will to win were less likely to be promoted to high command in the war. There can also be rational political explanations for gambling on war when the top political leaders would expect to lose their high positions under any outcome other than a decisive victory. (George Downs and David Rocke 1994 have shown how such a political incentive system could be optimal for promoting the interests of the electorate when they have less information than their leaders.) Such conditions seem more likely to apply in a nation once it has committed itself to a major war.

A different class of explanations may be needed to understand what could cause the original onset of a war. But one point which applied at the start of World War I is particularly worth mentioning here. The Chief of the German General Staff in 1914 was Helmuth von Moltke, the nephew and namesake of the commander who had engineered the great German victory in the Franco-Prussian war. Having attained this high position, what further aspirations could motivate the younger Moltke, other than the possibility of matching or exceeding the victorious achievements of his famous uncle? His personal situation could be a textbook case for when risk-seeking behavior may be expected. We should not be surprised that he would focus all his professional efforts on developing a military plan that offered the highest probability of achieving a glorious victory, even if it also entailed extraordinary risks of widening the scope of war.

Risk-seeking behavior could be driven, not only by a utility function that is relatively insensitive to large losses, but also by a perceptual bias toward overestimating favorable probabilities. In this regard, Ransom cites Dominic Johnson's (2004) book on *Overconfidence and War*, which in turn relied heavily on Irving Janis's (1973) general theory of "groupthink."

Janis (1973) explicitly recognized that groups which encourage critical debate can help people to improve their thinking. Indeed, anyone who has worked in an academic institution (or has seen Michael Frayn's brilliant play *Copenhagen*) should know that discussions with colleagues can be essential for catching and correcting subtle errors in our analysis. But when a group values internal cohesion and loyalty over debate, the group's social dynamics may inhibit critical judgment, instead of enhancing it. Such problems are particularly likely when a group faces conflict with external rivals. Then, according to Janis (1973), a basic human propensity to *groupthink* can involve (1) a fundamental belief in our group's inherent morality and our ability

to prevail in conflict, (2) stereotypical views of our rivals as too evil for us to negotiate with or too weak or too stupid to counter our efforts against them, and (3) group norms to deter or punish any questioning of these shared beliefs by group members.

Johnson (2004) suggested that a tendency to such groupthink or overconfidence in conflict may be an adaptive human trait which could have had advantages for survival in our evolutionary past. For millions of years, our ancestors have been social animals living in groups which would regularly have to defend their territory against rivals, and a group's ability to prevail in such contests would depend on its members accepting severe individual risks in fighting for the good of the group. So groups would be more likely to survive if their members had some inherited social instincts that could help them to override or re-direct their individual instincts for self-protection when their identified social group is in serious conflict against rivals. Socially-defined perceptual biases could serve such a function. But for this mobilizing purpose, an ideal bias would heighten both fear of what our enemy could do if not countered and confidence in our group's ability to counter the threat by working together.

The perceptual biases of groupthink, as described by Janis (1973), can improve a group's prospects in conflict in several ways. Overconfidence in the relative strength and courage of our own group can help to reduce the perceived risks of fighting for the group, and denigration of our enemies' morality can also help to suppress anyone's thought of surrendering to them. Individuals' belief in these perceptions of groupthink can be maintained against contrary evidence by the social norm of rejecting as disloyal any member who would question either the positive estimate of our group or the negative view of our enemies. In this way, groupthink can help to fortify our resolve to fight against our enemies. When our resolve becomes evident to our rivals, its impact can be further enhanced by a game-theoretic deterrent effect, because our willingness to fight would increase the cost for our enemies to fight against us and so may deter them from doing so. Furthermore, we might hope that their recognition of our high morality could also make them more willing to accommodate us or appease us. Thus, Janis's groupthink seems well-designed to improve a group's prospects in conflict both by increasing its members' resolve to fight and by helping to bluff or demoralize its rivals.

Of course, overconfidence can also harm a group by causing it to take ill-considered gambles. One noteworthy example may be the German decision to launch unrestricted submarine warfare in early 1917, in spite of warnings from America that it would enter the war to defend freedom of the seas against such German attacks. Ransom (2018 p159-161) suggests

that this decision largely resulted from Germans' overconfidence in the unproven ability of their submarines to prevent American assistance from reaching Europe. But Wolford (2019 chapter 13) uses game-theoretic models to suggest that Germans might have rationally figured that America would probably enter the war against them no matter what their submarines did, because Britain and France had borrowed so much from America that Americans would want to prevent a German victory which could make these loans uncollectible.

3. Game-theoretic models of war from its onset

Game theory provides an analytical framework for generalizing lessons learned from one instance of conflict to others, and so lessons from World War I can be usefully formulated in terms of game-theoretic models. Game theory requires us to consider all sides of the conflict and does not require us to put the blame on any one side. It would be too easy to explain destructive wars by blaming them all on monstrous leaders. As Wolford sagely observes, a game-theoretic analysis of World War I obliges us to view its leading participants as persons to be understood and to rationalize their decisions in terms of natural human goals, which is indeed to humanize them.

The first chapters of Wolford's book introduce game models in strategic form, with Nash equilibrium as the basic solution concept. The pre-war Anglo-German arms race is modelled as a Prisoners' Dilemma game where each player has two possible actions, and switching to the more aggressive action would increase the player's own payoff but would cause a larger decrease in the other's payoff. Thus, warlike behavior can be understood as a Nash equilibrium that is Pareto-dominated by another feasible outcome in the game, because both players could be better off if they both switched to their less aggressive actions.

This basic modeling point deserves more emphasis for students who are just beginning to learn the art of game-theoretic modeling. In the realities that we are modeling, people may choose among a myriad of strategic options, but a good model should strip away most of this complexity so that we can focus on the key essentials. Students often need to be told to simplify their model, but they must learn how to make the right simplifications. It would certainly be too simple to use a model of war where fighting was the only strategic option for each player, because an interesting explanation of war must explain why people would go to war instead of doing something else that we might have thought that they should do instead. More specifically, as war is costly and destructive, the primary question about war is why would people choose it

when some peaceful alternative could be better for everyone. Thus, a good model of war should include an outcome that represents war and at least one peaceful outcome that is Pareto-superior to war, so that showing how war is a Nash equilibrium in this model would then be an explanation of why people might choose war instead of better peaceful alternatives.¹

The logic of preventive war is an important early topic in Wolford's book. In 1914, Germany's army was clearly the strongest in Europe, but a Russian military modernization had some potential to make its huge army superior to Germany's by 1917. Fearing this possibility, Germany's leaders considered the potential advantages of a preventive war to weaken Russia before it became too strong to stop. Russia's alliance with France could be balanced by Germany's alliance with Austria, but Austria had refused to support Germany in a previous international crisis. Thus, Germany's best hope to eliminate the growing Russian threat would be in a preventive war over some issue that Austria would be bound to support. For this purpose, a perfect issue seemed available when Austria demanded retaliation against Serbia, an ally of Russia, after Serbian agents conspired to assassinate the heir to the Austrian throne. Wolford develops a series of game models to analyze the intricate logic of these international relations. Game models with more than two players can become useful when we are analyzing such situations where the rational strategic decisions of one nation depend on the anticipated incentives and decisions of several other nations.

Modeling decisions to go to war as a Nash equilibrium in a strategic-form game can show how, under some circumstances, national leaders might each find costly warfare to be their best available option, given the expected strategic behavior of others. But if the international game also had some alternative equilibrium that would be Pareto-superior to war then, one could ask, what would prevent responsible leaders from coordinating their expectations on such a peaceful equilibrium that they all prefer to war? Thus, James Fearon (1995) has argued persuasively that a rationalist explanation for war must also explain why nations are unable to coordinate on some peaceful outcome that would be better for everyone than a costly and destructive war. That is, for Fearon (1995), a rationalist explanation of war should convincingly show why the international game has no other Nash equilibria that would be better than war for all the players; it is not enough to show merely that war can occur in one Nash equilibrium of the international game.

¹ In chapter 4 Wolford considers a model of war where the "war" outcome is actually Pareto-efficient, but a few numbers could easily be changed to make one of the peaceful outcomes Pareto-superior.

Unfortunately, while it may be easy to verify that one particular outcome is a Nash equilibrium in a strategic-form game, proving that a game has no other Nash equilibria can be much more difficult. But incentive constraints from agency theory provide a way of bounding the set of equilibrium outcomes, even when the players' procedures for communicating and negotiating are not fully specified. Economic theorists regularly work with two kinds of incentive constraints: moral-hazard incentive constraints that apply when a player cannot commit to abstain from some problematic form of opportunistic behavior, and informational incentive constraints that apply when a player cannot be trusted to honestly share some private information. Fearon (1995) applies both kinds of incentive constraints to develop a powerful theory of rationalist explanations for war.

One of the triumphs of Fearon's approach is his demonstration that a preventive war by a currently dominant nation against a rising nation, such as Germany contemplated against Russia in 1914, can be understood in terms of moral-hazard commitment problems in a dynamic game. The currently dominant nation cannot be expected to accept any long-term agreement that would be worse for it than what it could get by launching a war now, while it has military superiority. On the other hand, the rising nation cannot be expected to fulfill any long-term agreement that would give it less than what it could get by launching a war in the future, after it gets military superiority. Under some circumstances, it may be impossible to find any long-term peaceful agreement that would satisfy both of these moral-hazard peace-keeping constraints, and then preventive war cannot be deterred. The key to this analysis is that the rising nation cannot credibly commit itself now to refrain from using its ability to threaten war in the future after power has shifted in its favor, but the currently dominant nation could prevent this shift of power by launching a costly war now. Conditions for such moral-hazard commitment problems to jointly eliminate any possibility of a peaceful agreement have been analyzed by Robert Powell (2006).

Fearon (1995) also showed that moral-hazard commitment problems can provide a theory of preemptive wars, which are driven by an expectation that whoever attacks first would gain a decisive advantage in war. As Stephen Van Evera (1984, 1998) has argued, changes in military technology can affect the comparative advantages of offense and defense in war, and this shifting balance between offense and defense can be a fundamental factor in determining the risk of war. For an international agreement to keep the peace, the agreement must not give any nation less than what it could get by starting a war, where it would have the advantage of initiating the first

offensive moves. These minimum peace-keeping payoffs for all nations would tend to increase when the advantage from the first offensive becomes greater. So if the initial offensive advantage becomes large enough, it could become impossible for any feasible agreement to keep the peace. Then the only hope for maintaining peace might be for nations to accept substantial constraints on their peacetime deployment of forces, to eliminate any potential for an advantageous surprise attack. Such a model was implicit in German arguments that Russia's mobilization in 1914 created a situation where it was impossible to expect peace.

Many statements by military and political leaders in 1914 appear to express beliefs consistent with the logic of preventive war or preemptive war applying in their situation (Jannen 1996), but we can also find good reasons for doubting whether the conditions of these theories actually applied then (see also Zagare 2011). Although nobody could be sure in 1914 about what would be the result of a Great War, the actual result in 1918 shows that a costly defeat for Germany should have been recognized as a realistic possibility, which could significantly relax the moral-hazard constraint for Germany to avoid war. And while military planners may have talked about advantages for offensive forces in early 1914, the military technology of that time (with machine guns and barbed wire but before the development of offensive air power) was actually quite favorable to defensive forces, as was proven by years of trench warfare. Indeed, evidence of substantial advantages for entrenched defenders had been available at least since the American Civil War.

Given this disjunction between leaders' statements and historical evidence about military realities, we should be open to the possibility that, in the crisis of July 1914, intelligent observers could be uncertain about how some key national leaders actually perceived the situation. Wofford introduces Bayesian games to model such uncertainty and show the possible role of informational incentive constraints in the failure of diplomacy to avoid the start of World War I.

In July 1914, Germany warned that it would have to fight to defend itself if Russia mobilized its larger army, but Russia mobilized anyway, and Germany's response was indeed to initiate the hostilities which started the Great War. Why did Germany's explicit warnings fail to deter Russian mobilization? The problem was that Russia's leaders considered it very unlikely that Germany's leaders would actually feel compelled to initiate a great European war just because Russia mobilized its army within its own territory. We could model Russian doubts by a game where Germany could be one of two possible types: a *preemptive type* which believes that Russia's mobilization would create conditions for a surprise attack to overwhelm Germany

unless Germany attacked first, or a *safe type* which believes in its defensive ability to withstand any attack on its territory. The preemptive type would feel compelled to launch its own preemptive attacks in order to defend Germany against a Russian mobilization, but the more-likely safe type would prefer to mobilize defensively rather than launch such a destructive war. Obviously the Russian leaders would prefer not to mobilize if they knew that Germany's leaders were the preemptive type, but the safe type of Germany's leaders would also have reasons for preferring that Russia should not mobilize its forces in July 1914. If the Russians did not mobilize, then Russia would have no effective threat to deter Austria from going too far in its punishment of Serbia. There was a broad consensus in Europe that Austria could justify some limited punishment of Serbia, but a complete Austrian conquest of Serbia then would be a significant change in the European balance of power. So the Russians could rationally believe that the German leadership was probably the safe type and was just trying to sound like the preemptive type in order to give its Austrian ally an opportunity to reorganize the Balkans and severely reduce Russia's future influence in the region. Thus, the necessity of war could be derived from an informational incentive constraint that prevented Germany from credibly signaling its preemptive type without starting World War I.

Wolford also uses a Bayesian game to explain how Germany's invasion of Belgium, which was the first step in the Schlieffen plan for a war against Russia and France, could cause Britain's leaders to join the war against Germany. In this model, the German invasion of Belgium was a shock that convinced the leaders of Britain that Germany's leaders were driven to achieve an unlimited military hegemony over Europe, which Britain had to resist. International treaties had guaranteed Belgian neutrality, and any nation that violates international norms should expect some punitive response from other nations. So people in Britain could infer that the German leaders would not have invaded Belgium unless they had wide ambitions for hegemony in Europe that would be too dangerous for Britain not to resist. That is, a violation of an international treaty could elicit a costly punitive response because, in equilibrium, others would interpret the violation as evidence that the violator had an aggressive expansionist type that had seemed unlikely before the violation. This is a Bayesian version of Thomas Schelling's (1960) general argument that even a small violation of international boundary can incite costly punitive responses when others expect that the unpunished violation would lead to more serious aggression in the future.

A peaceful international regime, such as the one that the Europeans had enjoyed for most

of the century before 1914, depends on nations respecting international norms and responding adversely against anyone that violated them. From the folk theorem of repeated games, we should understand that international relations are a dynamic game with multiple equilibria, where each equilibrium is supported by expectations that any deviation from prescribed behavior could provoke punitive responses by others, who would understand that such responses were essential for maintaining their own long-term benefits from the equilibrium. In this way, any advantage that a nation might expect militarily from initiating the first offensive in a war could be countered diplomatically by other nations' adverse response against the nation that broke the peace. But this equilibrium requires a broad consensus about which forceful actions are provocations, and which are justified punitive responses. Formal international agreements and diplomatic conferences can serve a vital function in maintaining a general consensus on these questions.

Before July 1914, peace had been largely maintained by a regular process of diplomacy among a group of nations with mutually recognized "great power" status. When responses to global events enabled any member of this group to increase its power, their diplomats could negotiate compensating gains for other members, so as to preserve the general balance of power. Imperial colonies abroad could provide a useful currency for distributing such gains, and so global colonial expansion could help to support European peace in the late 19th century (as noted by Ransom 2018 p9). But in July 1914, Germany's leaders did not want Russia to get any compensation for Austria's gains from punishing Serbia, and an effective diplomatic conference for the Serbian crisis was impossible without active German support (Jannen 1996 chapter 19). Then in August 1914, when Germany invaded Belgium under the Schlieffen plan, Europe's diplomatic consensus was utterly destroyed.

The Great War began on all sides with enthusiastic predictions of a short victorious war, apparent evidence of an inconsistent mutual optimism about military superiority, and many have considered such mutual optimism to be a basic causal condition for war (Blainey 1988, Debs 2020). But in fact it was the beginning of a long war of attrition that devastated Europe for over four years. So beyond the question of why the great powers of Europe descended into war in 1914, it is also vital for us to understand what game-theoretic analysis can contribute to understanding why the warring parties could not escape this destructive conflict until late 1918.

4. Modeling the duration of a war of attrition

Theories about the causes of war may suggest corresponding theories about how wars can end, as the end of a war would require the resolution of at least some of the issues that caused the war. So one can argue that, if a war has been caused by informational incentive constraints, then the war cannot end until these problematic uncertainties have been resolved, perhaps by information that is revealed in military combat. Alternatively, if a war has been caused by moral-hazard commitment problems, then the war cannot end until some of these moral-hazard constraints have been relaxed, perhaps by the military destruction of capabilities for at least one side in the conflict. These ideas have been considered by Wolford (2019, chapters 11 and 12) and have been developed in an extensive literature (including Slantchev 2003, Powell 2002, Powell 2004, Smith and Stam 2004, Goemans 2000, Levantoglu and Slantchev 2007, Fearon 2004, Wolford, Reiter, and Carrubba 2011, and Jackson and Morelli 2011).

However, the problems of asymmetric information and moral hazard that we have identified as potential causes of World War I seem less relevant to explaining the war's duration. If many Europeans had doubts about the seriousness of German warnings against Russian mobilization, those questions about Germany were convincingly answered by its invasion of Belgium in August 1914. If Germany was driven toward a preventative war by moral-hazard constraints that derived from the anticipated growth in Russian power, that power collapsed with the Russian Revolution in 1917; but the Russia Empire's collapse did not bring an end to World War I, even after the goals of preventative war were apparently achieved in the Treaty of Brest-Litovsk. In war, even when old incentive problems are resolved, the mobilization of vast military forces can itself create new moral-hazard problems that constrain people's ability to negotiate credible commitments.

Furthermore, effective negotiations require some shared understanding about how a compromise among rival concerns could be arbitrated. In a war to determine the supreme leadership of the world, it would be absurd to assume that the combatants could agree on an arbitrator whose judgments would have power over them all. As noted by Ransom (2018 p113), if the great powers of Europe had accepted Woodrow Wilson's offers to broker a peace agreement, his proposed "peace without victory" would have conveniently put the United States at the top of the global power structure, setting the terms to govern the postwar world.

Thus, although it has been argued that game-theoretic explanations for the onset of war should be based on models that have no better peaceful equilibria, it might be appropriate to

analyze the potential duration of war by models where a prolonged conflict is just one of several possible equilibria. After the war has begun, the existence of even one sequential equilibrium where the parties persist in a long and costly war of attrition may be considered as a potential explanation of how rational decision-makers could become caught in a mutually destructive war. The existence of other Pareto-superior equilibria that a mutually accepted arbitrator could recommend becomes irrelevant when the parties are at war in a struggle for supreme power.

Wolford's analysis of the war of attrition emphasizes the role of cost-minimizing military tactics and mutual understandings for limiting some aspects of the conflict. These are important questions. Schelling's (1960) analysis of bargaining and limited war gave rise to his theory of focal points in games with multiple equilibria, which has become fundamental to our understanding of social order (see also Myerson 2009). But Wolford does not emphasize the classic war-of-attrition model, perhaps because dynamic game models are not developed until quite late in his book. A version of this model can be found in Fearon (1998) (see also Hendricks, Weiss, and Wilson 1988).

Let us consider here a simple model of the war of attrition, using a modification of the notation from Fearon (1998). Nations 1 and 2 are contending for shares of a total flow of peacetime benefits with value 1 per unit time. Each nation j has demanded a share w_j for itself. Let v_j denote the amount that has been offered to nation j by the other nation's demand, so that $v_1 = 1 - w_2$ and $v_2 = 1 - w_1$. We assume $1 > w_j > v_j > 0$ for each $j = 1, 2$. Until one nation accepts the other's demand, the nations will be in conflict, which yields a payoff flow of $-c_j < 0$ per unit time for each nation j . Both nations discount future payoff flows at rate r per unit time, so that the present discounted value of j 's share when the conflict ends would be w_j/r if j wins acceptance of its demand, but it would be v_j/r if j concedes to the other's demand.

Each nation j can decide at what time t_j to concede and end the conflict by accepting the other's demand, if the other has not conceded yet. Nation j could be willing to concede at some point in the conflict only if its payoff from immediate concession (v_j/r) would be better than its expected payoff from waiting an additional dt units of time (at least), which depends on the probability of the other nation conceding to j 's demand in this time interval. Suppose that, at a point in time when neither side has yet conceded, nation j would believe that the event of a concession by the other nation has probability density q_j ; that is, the probability of the other nation conceding and accepting j 's demand in a short dt units of time would be approximately $q_j dt$ (to a first-order linear approximation in dt). Then for nation j to be willing to concede at this

point in time, we must have

$$(c_j + v_j)dt \geq q_j dt (w_j - v_j)/r.$$

In this inequality, the left side measures j's cost of waiting an additional dt units of time (getting the conflict payoff flow $-c_j$ instead $+v_j$), while the right side measures j's potential expected net gain from winning $(w_j - v_j)/r$ with probability $q_j dt$ in this interval. Thus, at any point in time when the conflict has not ended, j's willingness to concede or wait a bit longer would depend on whether the probability density q_j for the acceptance of j's demand is less than or greater than the critical success rate λ_j where

$$\lambda_j = (c_j + v_j)r / (w_j - v_j).$$

This game has an equilibrium where the concession time of each nation i is an independent random variable with an exponential distribution that has mean μ_i , where $\mu_1 = 1/\lambda_2$ and $\mu_2 = 1/\lambda_1$. In this equilibrium, as long as neither nation has conceded, the probability of nation 1 conceding in the next dt units of time would be approximately $dt/\mu_1 = \lambda_2 dt$, and the probability of nation 2 conceding in the next dt units of time would be approximately $dt/\mu_2 = \lambda_1 dt$. That is, each side is conceding randomly with a probabilistic rate equal to the critical success rate that makes the other side indifferent between conceding and waiting for a concession by its opponent. In this randomized equilibrium, each nation is willing to wait and let the conflict continue for any length of time, and there is no sure upper bound on how long the conflict might last. But these optimal concession times also include zero. That is, each nation is willing to concede immediately at the start of the game, and so each nation's expected equilibrium payoff must be equal to the amount v_j/r that it could get by conceding immediately. Thus, in this equilibrium, the expected cost of conflict for each side completely cancels out all the expected benefits from potentially becoming the ultimate winner. So this equilibrium offers an explanation for how rational actors can become trapped in a conflict like World War I, choosing conflict over concession so long that the war can ultimately cost more than what either side originally hoped to gain from winning.

However, this basic war-of-attrition model has two difficulties that should be discussed. First, we should recognize that this model has some implausible comparative statics for changes in the costs of conflict (c_j). Second, we must address the question of what could deter nations from offering a compromise settlement to end the conflict much sooner.

Holding fixed all other parameters in this model, if we increased nation 1's cost of

conflict c_1 , then the equilibrium would change by an increase of 1's critical success rate λ_1 , and thus nation 2's expected concession time $\mu_2 = 1/\lambda_1$ would decrease. So in this model, making war costlier for nation 1 apparently would make nation 2 concede sooner and so would increase nation 1's probability of winning the war. If this result seems unrealistic, it may be because something important in warfare is missing from this simple war-of-attrition model.

The willingness of both sides to continue the costly conflict requires each to have some hope of ultimately winning, and so the outcome must involve some random uncertainty. However, the simple war-of-attrition model includes no exogenous random variables, and so the randomization must come from the players' strategic behavior. A rational player makes random decisions only when the player is indifferent among the alternatives, and so in this randomized equilibrium each nation must always be indifferent between conceding and waiting for the other's concession. So if nation 1's cost of conflict were increased, 1's indifference between conceding and waiting would require a corresponding increase in nation 2's probability of conceding during any interval of time.

The problem with this argument is in the assumption that there are no exogenous random variables, when wars are actually full of random uncertainty. A war is a series of battles that have unpredictable outcomes which can be appropriately modeled as publicly observed random variables. For any game that has more than one equilibrium, the introduction of publicly observed random variables can expand and convexify the equilibrium set, because equilibrium expectations can be conditioned on the results of a public random variable in the subgame after it is observed.

Indeed, our basic war-of-attrition model has multiple equilibria. For each nation j , there is an equilibrium where nation j would be expected to concede as soon as possible, and so the other nation would never concede. Such an equilibrium could become focal whenever something makes people believe that nation j 's cause is hopeless, and this belief can become a self-confirming prophecy as it bolsters the other nation's confidence of an imminent victory. Even if both sides began the game with some hope of winning, their beliefs could shift to such an equilibrium in a subgame after a battle where nation j suffered a decisive defeat.

Now suppose that battles occur regularly during the conflict, and each battle generates random outcomes, some of which could be generally considered a decisive victory for one side or the other. So battles constitute a public random signals which can expand the set of equilibria. Suppose that, as long as neither side has had a decisive victory, the event of nation j achieving a

decisive victory in battle would have probability density q_j . As long as $q_1 \geq \lambda_1$ and $q_2 \geq \lambda_2$, each nation's hopes of winning by a decisive victory would be sufficient to motivate both nations continuing the conflict to a decisive military resolution. Indeed, if these two inequalities are strict, then both sides could be described as rationally optimistic about the conflict, in the sense that each side's expected payoff in the conflict is strictly more than what it could get by accepting the other's offer. A larger value of q_j would mean that battles have more likely outcomes that would be recognized by everyone as a "decisive victory" for nation j , which could depend not only on military realities but also on cultural perceptions in both nations.

Now consider again the event of an unanticipated public shock that increased nation 1's conflict cost c_1 , so that 1's critical success rate λ_1 suddenly increased. What should we expect after this unexpected parametric change? If λ_1 was still less than 1's military success rate q_1 , then the equilibrium could remain the same. But if the new λ_1 was greater than q_1 , then nation 1's chances of winning the war by decisive victory would no longer be sufficient to make nation 1 willing to bear its increased cost of conflict; and so we could reasonably predict that expectations should shift to the equilibrium where nation 1 concedes immediately. That is, the increased cost of conflict could cause nation 1's war effort to collapse. This seems a much more realistic prediction than the comparative statics of the simple model that neglected the randomness of battles.

This game's multiplicity of equilibria also offers a way of explaining how nations could be deterred from making a new offer to settle the conflict sooner. In any equilibrium where the two sides have consistent beliefs and positive expected costs of conflict, there must be a compromise agreement that could be better for both than what they expect to get from fighting. But each nation could fear that, if it publicly expressed any readiness to consider a compromise to end the war, then the result would be to make everyone focus on the equilibrium where this nation would quickly accept the other nation's original demand, as if "we are ready to compromise" would be interpreted as "we are ready to surrender."

World War I actually ended when people in Germany lost the will to fight after four years of slaughter. Although many game-theoretic models of war may treat a whole nation as one player in the game, great nations are actually vast organizations of individuals whose actions can form a coherent purposeful strategy only when they are coordinated by leaders who will have power and resources to reward individuals for their contributions to the general effort. When these millions of individuals lose confidence in their leaders or in each other's ability to

persevere in the struggle, then the national war effort must stop, as happened in first Russia in 1917 and then finally in Germany in late 1918. When a nation is on the verge of such a collapse of morale, its political leaders would get serious indications of their population's general exhaustion, but they would conceal this information as long as they could. So our dynamic model of war could realistically include, in any period of time, some small independent probability that each nation's leadership could change to an exhausted type that has secret evidence of a likely imminent collapse of its ability to fight. Such pessimism would make this type more inclined to accept any compromise for peace before its collapse. In this game model, there could be an equilibrium in which neither side would express any interest in compromise settlements unless it was on the verge of collapse; but then, in response to any such overture, the other side would confidently refuse any settlement that was not close to what it could expect from outright military victory. In this way, warring nations could be rationally deterred from initiating peace talks despite the terrible costs of conflict.

5. Modeling the players in international relations

Game theory analyzes models of situations that involve decisions by two or more players. In game-theoretic models of international relations, it is commonly assumed that the players are nations. In general, game-theoretic analysis relies on two basic assumptions: that each player will make rational decisions to maximize its own expected payoff, and that all players share a consistent understanding of the game and each other's strategies for playing the game. The analytical power of game theory is derived from these basic assumptions. But a modified framework that allows some limited exceptions to these assumptions might retain much of this analytical power while providing a better fit for some applied problems. So we should consider relaxing these basic assumptions about the players, the rationality of their decisions, and the consistency of their beliefs. In this section we reconsider the view of World War I as a game played by nations. Then the next two sections will consider how the rationality and consistency assumptions might be relaxed to better understand the problems of World War I.

Nations can often be seen as acting in a rational strategic way, at least approximately, because national leaders have substantial powers to coordinate and direct people's actions into a coherent strategy for advancing broad national interests, and national leaders can use redistributive powers to ensure that national gains will benefit people throughout the nation. So in our model of the war of attrition, for example, it seems reasonable to assume that decisions

about the continuation of the war effort are made strategically by national leaders because, although the millions of individuals fought in World War I with different personal motivations, they could only be brought together into an effective organized military force by the directives of their national leaders. National leaders may also have their own personal motivations, but they could not maintain their privileged positions of leadership if they did not generally use their powers to promote the broad interests of people throughout their nation.

The Westphalian model of international relations assumes that the world is partitioned into nations, and that generally recognized national leaders exercise supreme independent authority within each nation.² In reality, however, the organization of humanity has many more levels, both subnational and international, and national leaders are regularly constrained to respect the right of groups at other levels to exercise autonomous authority over certain decisions. Within each nation, people may identify with a variety of subnational groups, each of which may have its own autonomous leadership, and the power of national leaders generally depends on the trust and cooperation of individuals who exercise leadership at lower levels in society. Higher levels of international organization naturally develop out of nations' need for allies in defense and partners in trade. At each level of social organization, individuals may compete for leadership within their group, and different groups may contend for power and resources, and any of these competitive interactions could be the subject of a game-theoretic model. In particular, World War I can be understood as the ultimate contest for international leadership among the great nations of Europe (see Taylor 1954).

As Graham Allison (1969) observed about the Cuban missile crisis, some events in the history of World War I may be better understood when we relax the national-actor assumption and recognize the influence of decisions by subnational leaders and individual citizens acting for their own interests. For example, the assassination of Austria's Archduke Franz Ferdinand in June 1914 may be better understood, not as an act of the Serbian nation, but as an act of one Serbian political faction, which anticipated that the assassination would create political difficulties for Serbia's prime minister and so could reduce his chances of winning an upcoming election. Then in July 1914, a lack of international clarity about Austria's objectives in punishing Serbia was at least partly caused by the fact that the Hungary was an autonomous component in

² This usage of the word "Westphalian" was derived from the Peace of Westphalia, which ended the Thirty Years War in 1648. But the main issues of this war concerned the distribution of power in Germany between the Holy Roman Empire and its component principalities. So a federal division of power between higher and lower levels of political leadership was essential even in the original Westphalian settlement. See Andreas Osiander (2001).

the Austrian Empire, and the leaders of Austria had to negotiate with Hungarian leaders who favored more limited objectives (Jannen 1996). Finally, in the long war of attrition, the conditions under which a nation could collapse can be better understood when we recognize that a nation includes many individuals who may feel compelled to obey their national leaders' commands only when many others are doing so. Thus, a general compliance with government directives and a broad breakdown of national discipline can be two alternative equilibria in a more fundamental game that is played by all the citizens, and a publicly observed defeat in battle could switch people's focal expectations from one equilibrium to the other.

6. The possibility of an irrational decision and its consequences

When we look for actions in the history of World War I where an assumption of rationality might be problematic, the most important is the German invasion of Belgium under the Schlieffen plan in August 1914. By launching a massive preemptive attack on Belgium and France in response to a potential military threat from Russia, Germany brought all the great powers of Europe into a devastating war, in which Germany was ultimately unable to avoid its share of the catastrophic costs. The assumption that this attack was the result of a rational decision by the government of Germany drove many observers to conclude that Germany had a dangerously aggressive type of government; but people in Germany itself generally denied this conclusion. If we are willing to admit that leaders of great nations might have made some irrational decisions in modern history, this one should be the first on our list. However, if we are to work toward an analytical framework that tightly limits any exceptions to the rationality assumption, then we should seek some basic explanation for why Germany's leaders were unable to avoid this mistake in 1914.

Of course the Schlieffen Plan was a gamble, and the rationality of a decision to gamble cannot be evaluated by its outcome alone. But even given the information available at the time, the Schlieffen Plan should have seemed a bad gamble for Germany. In response to a mobilization of forces by Russia, the Plan stipulated that Germany should attack France through Belgium, and the attack on neutral Belgium would bring Britain into the war against Germany. Germans should have questioned the logic of a Plan that required them to make war against the most powerful nations of Western Europe in order to protect themselves from a potential threat from the East. Arguments for the Plan were based on an assumption that Germany could not defeat Russia while defending itself against France, which was Russia's ally. But Germany did

exactly that after 1916, when Ludendorff and Hindenburg put Germany's western armies into a defensive mode to release forces that then decisively defeated Russia and drove it out of the war. A version of this Ludendorff plan could have been even more promising in 1914, when the neutrality of Belgium would have shortened Germany's defensive lines in the west, and then Britain might not have entered the war against Germany. Indeed, Alsace and Lorraine had been annexed in 1871 to give the German army a good defensive line in any future war with France.

Certainly Russia's leaders began the mobilization of their forces in July 1914 with a belief that Germany would respond by mobilizing its own forces defensively, without immediately launching attacks on its neighbors to the east or west. The general diplomatic and political surprise when Germany invaded Belgium shows that sophisticated European observers in July 1914 did not believe that Germany's self-interest would require it to launch a European war on the widest scale before anybody had attacked Germany.

We have noted that Moltke, the German Chief of Staff, may have had personal reasons to prefer the aggressive Schlieffen Plan, which offered the best chance of achieving a military triumph that could rival the accomplishments of his famous uncle. But any successful organization should have ways of channeling the actions of many individuals, who have different personal goals, to support common goals that serve the general interests of the organization; and the imperial government of Germany in 1914 was certainly a successful organization.

As Janis (1973) observed, groups which encourage critical debate can help people to improve their thinking, but social dynamics may inhibit critical judgment in a group that values internal cohesion and loyalty over debate. By this standard, we may expect rational inference among European diplomats, who could benefit from broad discussions and debates with others in the decentralized multinational network of diplomacy. This prediction seems broadly accurate in the complex diplomatic maneuvering of July 1914 (see Jannen 1996). Although there were a few diplomats whose personal biases seemed to exacerbate the crisis, notably France's ambassador to Russia and Germany's ambassador to Austria, even they might actually illustrate a rational diplomatic strategy of sending militant hardliners to reassure key partners in a military alliance.

However, military plans are formulated in secret by small tightly-controlled teams. Military planners may be experts in their profession, but in novel or non-routine tasks, basic mistakes can go uncorrected without independent review. At the key moment of decision on August 1, 1914, Moltke revealed to the political leaders of Germany that the only plan that they

had prepared for responding to Russian mobilization required Germany to attack France through Belgium. When the Kaiser suggested that the bulk of the German armies should be mobilized against the Russian threat in the east, with just limited defensive forces in the west, Moltke told him that it could not be done, because there was no prepared plan for implementing such a strategy, and the deployment of millions of soldiers could not be improvised. The power of the German army depended on its superb logistical planning, but any army could degenerate into a disorganized mob if it were deployed with no plan for its supply. (See Van Evera 1984 p85, and Jannen 1996 p298.)

Since 1914, military planners have accepted a doctrine that civilian leaders should expect them to prepare several alternative plans for responding to any anticipated crisis.³ But in 1914, complex plans for using railroads to move and supply hundreds of thousands of troops were still a relatively new innovation. In 1870, the Germans defeated France because the elder Moltke had crafted a better logistical plan, which then defined the state of the art for modern military plans that required long and careful preparation (see Howard 1961). A generation later, the younger Moltke invested years in meticulously crafting one incredibly risky plan for German mobilization. Other strategies for responding to the dangers of a two-front war against Russia and France had also been considered by Alfred von Schlieffen before 1906, when he was succeeded as Chief of Staff by the younger Moltke, but by 1913 Germany had only one military plan for fighting Russia and France, regardless of which nation started the conflict (see Zuber 1999, and Mombauer 2005 p875). The secrecy of military planning meant that Moltke's failure to prepare any safer alternative mobilization plans could not be known or debated by the wider political leadership of Germany until the moment of crisis came, and then it was too late to formulate any alternatives. In that sense, the disastrous decision to implement the Schlieffen Plan could be considered the result of a basic technical mistake, one that subsequent developments in military doctrine have helped to make less likely.

Game theorists know that opportunities to reconsider the provisions of a strategic plan before implementing them can be important for rational decision-making. When strategic plans are formulated *ex ante*, the expected value of a plan might not be significantly reduced by costly mistakes in its responses to unlikely contingencies. The emphasis on sequential rationality in game theory reflects an understanding that people may think much more carefully about how to

³ If this doctrine was developed in response to the disastrous consequences of the Schlieffen Plan, then perhaps we should be grateful that this lesson was learned before the development of nuclear weapons.

respond to some contingency when it actually occurs than when it is merely a remote possibility.

As Wolford rightly argues, we can gain important insights into the problems of war when we try to explain leaders' choices as rational decisions in terms of natural human values. But what would happen if we tried to rationalize a surprising decision that was actually a mistake? The surprising move could be rationalized in a Bayesian game by hypothesizing that the decision-maker has an unusual type with preferences or beliefs that would induce such behavior. This hypothesis could then lead to an expectation that the agent would repeat this behavior in the future, which we might not predict if we understood the surprising move to be the result of a one-time mistake. Thus, Germany's surprising invasion of Belgium in 1914 could cause people in Britain to infer that Germany had aggressive expansionist leadership, while people in Germany might consider such beliefs to be unjustified British prejudice.

7. The creation of inconsistent beliefs in war

We have seen that Russia's decision to mobilize in spite of German warnings could be analyzed as a Bayesian game with two possible types for Germany, where a preemptive type, from which the warning would be sincere, had difficulty convincing others that it was not the more-likely safe type, from which the warning would be a bluff. In terms of this model, Germany's invasion of Belgium could be seen as a costly signal that would cause others in Europe to update their beliefs about Germany's type, as they realized that the warning was not a bluff. The theory of Bayesian games teaches us that such costly signals can convey information that helps to reduce the asymmetry of information in the game, but this aspect of the theory does not seem to fit the events of August 1914. In fact, one can argue that the shocking news of Germany's invasion of Belgium may have significantly increased the asymmetries among Europeans' beliefs about Germany.

In August 1914, Europeans became deeply divided about the justice or injustice of the crucial events that started the war. A peaceful international equilibrium may require punitive responses against those who disturb the peace, but in such a dynamic equilibrium there must be some basic agreement about how to distinguish unjustified provocations from justified punitive responses. In this sense, a shared understanding of international justice was essential to the peace. Before the war, the great powers of Europe had maintained a broad consensus about diplomatic norms for managing a wide range of international disputes. But Germany's invasion of Belgium took Europeans outside the manageable range, and then Europe's international

consensus was shattered. The leaders of different nations offered different interpretations of how the norms of Europe's old equilibrium should apply to the events that started the war, each framing their own forceful actions as justified responses to another's provocations. The leaders of Germany condemned Russia's mobilization and military coordination with France as intolerable provocations, to which the Schlieffen Plan was a justified response (see Germany Auswärtiges Amt, 1915). But in Russia, France, and Britain, Germany's initiation of hostilities and invasion of Belgium were judged to be acts of unjustifiable aggression which demanded forceful resistance.

In each nation, people generally accepted their leaders' expressed interpretation of these events, with a sincerity that people on the other side found hard to believe. In spite of a common cultural history going back thousands of years, people in neighboring countries were radically divided by starkly inconsistent beliefs about the justice or injustice of major events from the day that the Germany army entered Belgium. Years of warfare did not reduce these differences between beliefs in the contending nations. (For example, compare the postwar perspectives of Poincaré 1925 and Marx 1926.) To people on each side of the conflict, their adversaries' actions were obviously unjustifiable and so had to be interpreted as compelling evidence of their adversaries' fundamentally malicious nature. Thus, patterns of groupthink created a stark asymmetry of beliefs in Europe, where each side felt sure of its own manifest morality and saw only malevolence in the actions of the other side.

In Bayesian games, we usually study differences of beliefs that come from players getting different information about some unobserved factors that affect outcomes and payoffs in the game. But in August 1914, the nations of Europe were divided by inconsistent strategic beliefs about how their old international equilibrium should apply in the subgame where they suddenly found themselves after Germany invaded Belgium. These differences in beliefs were derived from the start of the war itself.

Different beliefs about the start of the war could also cause significant changes in people's effective preferences. The German belief that this terrible war had been caused by a rising military threat from Russia and France could cause people in Germany to prefer that Russia and France should be severely weakened, so that they could never again threaten Germany in this way. Thus, national leaders' justifications for the war could effectively persuade their populations to demand more ambitious war aims, and so the onset of war could itself create new national preference-types, about which others might be uncertain. (See also Fischer 1967.)

The fact that people in each warring nation could feel certain that any moral European should agree about the justice of their side's actions at the start of the war shows that these beliefs were game-theoretically inconsistent. However, this inconsistency was derived from the very factor that makes consistency a good assumption in most applications: the normal imperative for everyone to accept the focal judgments of generally recognized leaders in their society.

As Schelling (1960) has emphasized, games with multiple equilibria are a pervasive fact of life in human society, and we can find many games where coordination can help to avoid inefficient equilibria that would be very costly for everyone. So in any society, the coordination that is provided by norms and leaders is essential for people's welfare and security. The power of leaders in society can be fundamentally derived from their role in determining the focal equilibrium that people will play in games that have multiple equilibria (Myerson 2004a, 2006, 2009). But this vital coordination ultimately depends on everyone's willingness to accept authoritative judgments from the highest leaders of their society. So in any successful society, we should expect to find strong social norms against questioning the universal validity of such judgments. Furthermore, when a society finds itself in Darwinian competition against rival groups, behavioral patterns like Janis's groupthink could be functional adaptations for shielding members of the society against any demoralizing influence from the rivals' leaders.

In modern Europe, the principle of national sovereignty has meant that each nation's top political leaders should be accepted as the ultimate coordinating authority within their nation. So when a great war began, people in each nation would generally accept their national leaders' expressed judgments about the events that started the war. Within each nation, any questions about the universal validity of their national leaders' judgment in this vital matter could be rejected as a menace to social cohesion. Indeed, this result would be the prediction of Janis's groupthink theory. But from a game-theoretic perspective, it could constitute an inconsistency of national beliefs about international relations, even though it has been induced by the norms of social cohesion that make game-theoretic consistency a good assumption for interactions within each nation. Consistency of international perceptions would require a system of basic agreements among the sovereign national political leaders; but by definition, a state of war means that such agreements have been shattered.

Thus, we must admit a regular possibility of game-theoretic inconsistency among the beliefs of people in different nations when they are at war with each other. An initial consistency

of beliefs could be a good assumption for models to explain the onset of war, where the nations are assumed to start with peaceful international relations, but game-theoretic consistency (like truth) may be among the first casualties of war.

Conversely, when we are trying to understand how wars end, we should recognize that a transition from war to peaceful international relations would require the construction (or reconstruction) of a broad international consensus about the vital questions of justice and authority that divided the groups in conflict. This consensus could be achieved either by negotiations among the leaders of the two sides, or else by the winning side replacing the leaders of the losing side, where the latter alternative could require the winners' forces to occupy the losers' communities for some period.

Peace is not just an armistice in which weapons cease firing. Peace is a relationship between nations that have a mutually accepted framework for resolving disputes and maintaining consistent strategic expectations in transactions between them. If the nations retain their separate independent leadership then their national leaders must respect each other and accept a shared framework for negotiations to realize mutual benefits of coordination. That is why, in game-theoretic analysis of a transition from peace to war, it may be reasonable to start with an assumption that the nations would coordinate on an equilibrium that efficiently avoids costly conflict if one existed. But for independent nations to make a transition from war to peace, the existence of Pareto-superior peaceful equilibria is not enough, because someone must take the lead in identifying which one they will implement, which means defining the principles for their new working relationship. The warring nations must develop a shared concept of justice for the postwar world.

From this perspective, we can see the final failure of World War I. The war was a contest to define a new focal equilibrium for Europe, and peace would require a new international consensus to be forged either by negotiation or by conquest. At the end of the war, however, Germany was still unconquered, and yet its representatives were excluded from the long peace negotiations in Paris. It was understood that some nations had joined the Entente's Alliance during the war so as to get a more influential seat at the winners' table in the peace settlement; but the Allies' negotiations with each other took so many months that, in the end, they effectively excluded the postwar German leadership from any role in defining Europe's new order. The resulting treaty, with the War-Guilt Clause and Reparations, perpetuated Germans' inability to accept the Allies' concept of a just order in Europe, which poisoned politics in Germany and set

Europe on the path to a second world war (Myerson 2004b).

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