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The Chain Store Game Revisited

A Game Theoretic Approach to Insecure Exchange in the Shadow of Conflict

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Abstract

Long-distance trade suffers from ineffective contracting and high transaction costs. Such trade can be defined as insecure exchange as it is conducted at the mercy of the regional powers, be they involved in the exchange or otherwise in a position to affect it. A predominant power engaging in international trade will seek to minimize its transaction costs by forcing regional powers to abstain from practices that threaten the security of the exchange. In this paper, we apply a game theoretic reputation based model by Treisman (2004) and show that a game of one hegemon and two challengers can result in a deterrence equilibrium. This enables economizing on forceful upkeeping of safe long-distance trade in insecure environments. We also show by historical examples that such a deterrence equilibrium could occur in reality, should the conditions be right.

Keywords: reputation, repeated games, chain store paradox, conflict, property rights
JEL: C72, C73, D74, D82, D83, F13, F51, L14

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The commerce besides which any nation can carry on by means of a river which does not break itself into any great number of branches or canals, and which runs into another territory before it reaches the sea, can never be very considerable; *because it is always in the power of the nations who possess that other territory to obstruct the communication between the upper country and the sea. The navigation of the Danube is of very little use to the different states of Bavaria, Austria and Hungary, in comparison of what it would be if any of them possessed the whole of its course till it falls into the Black Sea."* - Adam Smith (1776).

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1. Introduction

1.1 Background

As trade and economic interdependence continues to expand in the world, countries venture into new geographical areas, far away from the safety of the nation's borders. Economic research has traditionally built on the assumption of secure property rights and their enforcement being costless. This has provided valuable insights, but as with the nature of simplifications, it is not always the most accurate representation of reality. The importance of property rights in enabling efficient cooperation and growth is well documented; see for example Coase (1960), , Libecap and Wiggins (1984), Libecap (1989), and North (1990). Throughout the course of history there are numerous cases where the property rights of governments and corporations have come under threat once outside their jurisdiction. As trade moves beyond national boundaries and small scale exchange, the items of trade are subjected to new institutional environments and authorities, with a comparably larger underlying risk of conflict. Scholars in international relations commonly depict international politics as taking place in "anarchy", that is without a central authority. The lack of a common authority or government means that order becomes partly dependent upon bargaining.

Today, 90% of world trade takes place on the oceans and in the period between 2002-2012, U.S. exports to Africa and the Middle East alone, now total over US$100 billion (WTO 2013). These are also regions with some of the highest rates of corruption in the world (see figure 1A in the appendix). As trade routes extend to complex regions governed by erratic rulers, the potential gains of trade from expanding into these areas comes at the price of the willingness and capability to make sure that goods and people can travel safely and efficiently**.** The costs associated with protection are not only through the risk of appropriation, but also from less direct sources such as the payment of bribes and facilitation of ease of passage. Sequeira and Djankov (2008) for example find strong evidence of corruption in African ports that can lead to a 14% increase in shipping costs, and the costs are used for, among other things, protecting cargo. A historical example of insecure exchange is the trade with the West Indies, when the trade volume was low, the costs of eliminating piracy were deemed too great relative to the benefits from trade and therefore

considered not worth the effort (North and Thomas 1971). Indeed, much of historical trade has been conducted with conflicts, "guns", playing a major role, be that as a guarantee of safety, enabler of appropriation or something in between. As global interconnections become increasingly dense, regional disturbances can have substantial effects on the world economy. In such circumstances historical interactions have at times resorted to the constant, universal language of military power - and the economic logic of such enforcement is what we seek to explore in this thesis, specifically in the context of a powerful hegemon conducting trade in the vicinity of several smaller adversaries. The U.S. Navy for example conducts numerous freedom of navigation (FON) operations each year, in which excessive maritime claims are responded to with stabilizing military operations, and several other actors conduct various other operations with similar purpose. The issue of creating economic and political institutions that effectively induces economic growth remains a central issue in economic history and development, and while enforcement through intervention is often costly, understanding its logic is an important part of the "guns vs. butter" (see Skaperdas et al. 2001 and Hess 2009 for an overview) dilemma.

1.2 Research question

The research question we approach is why a hegemon would be willing to incur short-term costs through conflicts against challengers that do not pose a direct military threat, and how this can be explained by a long-term perspective on the economic benefits from deterrence.

This is approached by examining the economic dilemma of maritime insecure exchange that takes place in regions with insecure property rights due to a less clearly defined authority, and how maritime interventions with regards to reputation facilitate such trade. It is illustrated through a game theoretic analysis focusing on the role of reputation for a large player facing several long-lived small opponents.

The deterrence model used sheds light on the observed conflictual behavior that provides the basis for our research question and gives an explanation for the rationality behind incurring short-term costs from conflicts in order to gain long-term trade benefits.

The paper is organized as follows: The following section reviews previous literature on two topics; conflict and reputation, followed by a summary which links the existing body of knowledge to our research question. The third section describes the method. This is followed by the fourth section in which the model is presented. The fifth section analyzes some important aspects of the model and relates them to real events, and lastly the sixth section concludes the paper with a summary and a discussion.

2. Previous research

2.1 Conflict

War represents an almost incommensurable cost, yet in the field of economics it has long been given relatively little attention. Conflict is costly, both in terms of financial expenditures, casualties, psychological trauma and political implications. Diverting resources to conflicts leads to a pareto-inefficient outcome compared to nonviolence, due to the inefficiency inherent in the destructiveness of conflict. If the political reasoning is expanded to take into consideration how the actions of today might affect future interactions, the situation changes and conflict may become more appealing. History is paved with wars as a result of supposedly rational deliberations of political leaders. Why does war occur instead of negotiated settlements? According to the Coase (1960) theorem, if the transaction costs are sufficiently low and both parts have perfect information, bargaining between two players should lead to an efficient outcome, regardless of the resource allocation. Efficient Coasian bargaining is, as Coase himself acknowledged, a historically rare occurrence, and history indeed demonstrates plenty of examples of conflicts and pareto-inefficient solutions. Haavelmo (1954) was a pioneer in modeling the dilemma between production and appropriation. He did so in a general equilibrium setting in order to better understand economic development. His work on this topic does, however, not seem to have inspired many of his contemporaries as it remained a relatively unexplored subject for several decades, resurfacing strongly first in the 1990s.

Garfinkel and Skaperdas (2007) introduce a model that illustrates the choice between secure autarky

and insecure exchange. This choice is due to a player not having completely secure possession of their traded goods, requiring protective measures to guard against the theft of those goods by others. Each party has a secure endowment of labor which is transformable on a one-to-one basis into "guns", or alternatively used on land, which is the means to produce goods for consumption (welfare). They show that in equilibrium, the result is suboptimal welfare compared to the ideal state of secure property rights and that in the transition from secure autarky to insecure exchange, the resources spent on guns result in a lower welfare. Anderson and Marcouiller (1997) also look at equilibriums in the form of autarky, insecure exchange and secure exchange. As they include the possibility of a negative relationship between terms of trade driven by specialization and security, they find that increased security can have a harmful effect, and that this leads to cases of what they define as "immiserizing security". Grossman and Kim (1995) similarly find that a poor agent might be better off in an equilibrium with less secure claims to property. The authors also find that a nonaggressive equilibrium between appropriative and productive activities requires that offensive weapons are not too effective against defensive fortifications or that predation is sufficiently destructive. Veugelers (1993) looks at one instance of insecure exchange, by studying the relationship between multinational firms and host governments attracting foreign direct investment through coordination and signaling. The author focuses on how reputation building from the host government can facilitate credibility and create a safer climate for multinational enterprise investment. He finds that such reputation building from the host government depends on if future payoffs are valued highly enough and if history matters, that is if history influences potential investments.

Garfinkel et al. (2012) explores the importance of power as the assumptions of safe property rights and costless enforcement are relaxed, and how threats are dependent on the military power available and how this matters for trade. This is done by augmenting simplified Ricardian and Heckscher-Ohlin models with a non-traded good in the form of guns. Anderton et al. (1999) also use a Ricardian trade model with the possibility of appropriation in a sequential one-shot game, and show that conflict can be avoided by exchange, but that this happens at a cost that modifies the exchange itself.

The further away a country moves from its immediate vicinity, the more complex and risky contracting becomes. In a smaller, more local environment, the facilitation of exchange can more easily be built upon informal norms. Expansion into large-scale and long-distance trade challenges these norms and requires more formalized rules which reduces transaction costs (see North 1990, 1991, and Greif 1993). Dixit (2004) has formalized diminishing returns in the efficiency of a community dependent on informal governance (Rauch 2005). Institutional convergence in the form of economic agreements and organizations enables increased trade and can be seen as a form of security arrangement. Delgado et al. (2013) examine the effect on developing countries that implemented the TRIPS agreement that regulates intellectual property rights protection in knowledge-intensive goods. They find that trade in these goods increases relative to other goods, which lends support to the argument that institutional convergence, here in the form of regulation, facilitates exchange. Kimbrough et al. (2008) develop an experimental model in order to examine how different historical conditions influence the development of exchange. They use two treatments, historic property rights (PRH) and no historic property rights (NPRH), and they find that the PRH treatment develops wealthier and more equitable economies, and in particular as they allow for long-distance trade.

Schelling (1966) made the distinction between violence built on coercion and violence built on brute force. The scope of this paper is more in line with violence built on coercion, which is the use and threat of violence as a bargaining tool, or perhaps rather as a long-term economic efficiency tool. Schelling also coined the famous phrase "A reputation for resolve is one of the few things worth fighting for." (Mercer 1996). It was he who introduced the concept of coercive diplomacy, which focuses on the importance of violence in establishing a threat of further violence as the key mechanism to get the desired behavior. This punishment must, in order to be efficient, be made contingent on the adversary's behavior through communication.

Fearon (1995) adopts a rationalist perspective and argues that as wars are costly and risky there should be a range of bargaining options that are more beneficial to both parties. However, this is not the case due to rational miscalculations caused by lack of information and relative power that

prevents efficient bargaining, but as Fearon acknowledges, this does not explain why diplomacy or other forms of communication are not used to avoid such costly miscalculations. Fearon focuses on two main mechanisms to explain why rational states fail to bargain: the role of private information about resolve and capability, and states inability to credibly commit. Powell (2006) critiques informational explanations to failed bargaining due to what he considers their failure to explain prolonged conflict, and how the informational approach comes up short in a historical analysis. Powell argues that bargaining indivisibilities are better seen as commitment problems, and emphasizes how shifts in the distribution of power can lead to war. Skaperdas (1992) finds that coercion through warfare or merely the threat of war can establish property rights outside contractarian means and cooperation in a static setting.

Hirshleifer (1990, 1991) illustrates what he calls the paradox of power, that in many conflicts, the less-endowed side improves its position compared to the better-endowed side. One of his findings is that the comparative advantage of the less-endowed side can be overcome if the decisiveness of conflict is sufficiently great, so that a given ratio of fighting is disproportionately effective in determining the outcome of the conflict. Hirshleifer argues that improvements in military technology has led to such greater decisiveness.

Our model expands on the underlying ideas behind "trade in the shadow of conflict" (see for example Anderton et al. 1999 and Garfinkel et al. 2012) by developing a theoretical framework that links the actions necessary to facilitate exchange in the long-run through reputation building, to the demands of long-distance trade. The expansion of trade to less politically secure environments in recent decades and increased interdependence has created a situation in which reputational concerns are of increased significance to a hegemon concerned with efficient upkeeping of a global trade policy.

2.2 Reputation

Reputation functions as a link between past behavior and future expectations. It can be of huge importance in a setting with imperfect information where players are not equally well informed about parameters that affect payoffs and strategies.

Selten (1978) first described the chain store paradox, which represents a conflict in an industrial organization setting. It can be described as an entry deterrence or concession game with a discrepancy between the plausible game behavior and game theoretically correct reasoning.

In the chain store game, a monopolist player has branches in 20 towns, numbered from 1 to 20. In each of these branches there exists a competitor, k (numbered from $k = 1, 2, 3, ..., 20$). The k different potential entrants gradually accumulate enough capital to enter the market, one by one. As player k accumulates enough capital he must choose whether to open a shop (enter) or use the capital in some other way (out). If he does choose to establish a shop, then the monopolist has to choose between two price policies for the specific branch. He can either adopt an aggressive response (fight) or a more lenient cooperative approach (acquiesce). The profit in town k are higher if the monopolist acquiesces, but even higher if no shop is established at all. If the monopolist fights, it is better for player k not to enter at all in terms of profit.

Consider the $20th$ case where $t = 20$, the entrant gets a payoff of 1 if he chooses an alternative investment and stays out of the market. If he enters the market he gets a payoff of 2 if the monopolist acquiesces, but a payoff of 0 if the monopolist responds aggressively by fighting. From the monopolist's point of view, if the other player enters the market, he can either acquiesce and receive a payoff of 1, or fight and receive a payoff of 0. In the short-run situation here in the final round where $t = 20$, it is therefore preferable for the monopolist to cooperate. Consider now the previous game, where $t = 19$, the potentially aggressive behavior from the monopolist would not deter player 20 as $t = 19$ is analyzed independently. The threat of fighting is not credible, cooperating in the final round is a dominant strategy for the monopolist due to the dynamic

inconsistency that the monopolist faces. The induction theory inexorably extends this logic throughout the rounds, and concludes that each player $1, ..., 20$ should choose to enter the branch and the monopolist should choose to cooperate. Selten thus finds that the only subgame perfect equilibrium with a finite number of markets is for the entrants to enter and the monopolist to cooperate. The chain store paradox stems from the intuitive belief that it can be more beneficial for the monopolist to act aggressively early in the game if it can deter future entrants, while backward induction tells us this is not the case. In Selten's model the incumbent cannot change the entrants expectation about its future behavior, which effectively dissolves any potential reputation effects.

Rationality and perfect information, which are part of the rules of the game in Selten's original chain store paradox, are of course strong assumptions. By merely casual empiricism, laboratory experiments or by studying previous behavior, it is clear that players often deviate from the purely rational maximizing strategy (Aumann 1997). Selten (1978) approached this observation and the chain store paradox by arguing that decision making can be divided into three levels: the routine level, the imagination level and the reasoning level. While the reasoning level, which is the standard in game theory, attempts to analyze the situation in a rational way by considering both past experience and logical thinking is the ideal way of taking decisions, Selten argues that many decisions are instead taken at the imagination level. This limits the visualization (and subsequently rationalization) to merely a few rounds and is from Selten's point of view an explanation as to why deterrence continues to occur and influence decisions (see Selten 1989 for his revisit of these ideas). Rosenthal (1981) constructed a game called "the Centipede game" which was designed to be particularly complicated with regards to backward induction, in order to discuss the paradoxical implication of games such as the chain store game. When this game is played the strategies employed often differ substantially from the theoretically predicted behavior (see McKelvey and Palfrey 1992 for empirical evidence). As Rubinstein (1999) puts it: "It seems that the real problem is that whereas a proof by induction is a standard tool in mathematics, it is not part of routine human reasoning." One could argue that discussions and considerations such as these and why rationality sometimes falter are precursors to later ideas on cognitive decision making (see for example Kahneman et al. 1982, Kahneman 1994, Dawes 1996 and Tetlock 2005). A more experimental

approach to the limits of backward induction in behavior can be found in Camerer (2002).

The chain store paradox has attracted much attention, and it has been augmented and analyzed in different ways to illustrate how aggressive and cooperative behavior in similar situations can be understood (see for example Kreps and Wilson 1982a, Milgrom and Roberts 1982, Fudenberg and Kreps 1987). By introducing different players with exogenously given "types", and making the information about what type the other player is uncertain, several interesting aspects emerge. The uncertainty can be utilized since players are committed to different strategies with a positive probability, and by playing a specific strategy a player can build a reputation for being of the specific type (the approach which transforms a game of incomplete information to a game of imperfect information, see Kreps and Wilson 1982b, can be traced back to Harsanyi 1967). This might in turn have an effect on the potential opponents beliefs about the game, and lead to a more or less beneficial situation for the hegemon. Recently, authors such as Bohren (2011) have shown that reputation dynamics can appear even without uncertainty about the player's type.

Jung et al. (1994) conduct experimental tests on an entry deterrence game with short-run players, and find support for the existence of a sequential deterrence equilibrium, even with a "weak" incumbent. Massó (1996) showed how in a game with perfect information, but with uncertainty with regards to the order in which the entrant faces the incumbent, and without perfect observation of prior history, there exists a subgame perfect equilibrium in which entry can occur. Clare and Danilovic (2010) conduct an empirical investigation into whether states do actually act as if their reputation for resolve is at stake in conflicts, and find support for their argument. They do this by focusing on measuring how future behavior depends on previous actions. They find strong evidence in support of previous irresolute behavior leading to an increased likelihood of initiating and escalating conflicts in the future. The substantiality of these findings unsurprisingly depends upon if there are more than one rival in the strategic context. Similar to Press's (2006) theory of "Never Again" which proposes that costly concession in an earlier stage will inhibit future concessions. Walter (2006) analyzes government responses to domestic separatist movements and find evidence in support of that whether governments accommodate separatist movements depends upon a future

impact assessment and that actual intervention leads to fewer challenges in the future.

Fudenberg and Kreps (1987) looked at when entrants challenge an incumbent or "monopolist" simultaneously, instead of just sequentially. They find results in which an incumbent's reputation may dominate the game, even though entrants are no longer sequential, but instead simultaneous, however this result is rather sensitive to the structure of the game.

2.3 Summary of previous research

To summarise, the importance of property rights, the difficulty of and importance of efficient contracting has been thoroughly explored by, among others, Coase (1960), Libecap and Wiggins (1984) and Libecap (1989). It has also been examined empirically by Delgado et al. (2013) and Veugelers (1993), and shown in a laboratory setting by Kimbrough et al. (2008).

The relaxation of the, in much of economic research, ubiquitous assumption of secure property rights was made early on by Haavelmo (1954) and later by for example Hirshleifer (1990, 1991) and Skaperdas (1992). Yet the link between insecure property rights and (insecure) exchange is a rather new area (see for example Anderson et al. 1997, Garfinkel and Skaperdas 2007, 2012).

The conceptual link between these different strands of research through the notion of conflict and reputation is what we aim to provide, as we do not consider it to be investigated in the context that we seek to explore. It is the implications of pursuing a policy of trade expansion into areas where contracting is difficult and transparency lacking that we link to the failure of bargaining and the role that this leaves for conflicts and reputation building. The conflict and the rationalization of it - to return in an alternative way to what Powell (2005) and Fearon (1996) explored - is examined by making use of the insights from the literature on reputation, with the starting point being Selten's (1978) chain store paradox, its "solution" by Kreps and Wilson (1982), Milgrom and Roberts (1982) and a simplified adaptation by Treisman (2004).

3. Method

We investigate our research question by applying a game-theoretical model by Treisman (2004), but in a different context. Treisman primarily focuses on explaining the role of appeasement for a resource constrained central power, and analyzes British policy in the 19th and 20th century (see also Anievas 2011), and Spanish policy in the 17th century. We will instead focus on deterrence without resource constraints by a very powerful hegemon intervening in economically insecure regions. We illustrate a model that links the difficulty in efficient long-distance trade due to insecure environments, with conflicts in the form of costly fighting, through the reputation effects necessary for deterrence.

The model is a four-period game, featuring one hegemon, that can either be strong or weak, and two challengers. The hegemon's true type is exogenously given by "nature" and unknown to the other players, but the probability of each type is common knowledge. Regardless of type, the hegemon is powerful enough to operate without constraints on its enforcement resources. In the first and third period the challenger must decide whether to challenge the hegemon, or to accept his authority. The hegemon responds in period 2 and 4, by doing nothing if the challenger accept the hegemony, or by either fighting or acquiescing in the event of a challenge. The challenger's decision will depend on his expected payoff from each of his two choices, while the hegemon decides based on his expected return from all periods. After period 2, the second challenger will update his beliefs of the hegemon's type based on the actions in period 1 and 2. There is a fixed cost of fighting and value at stake in the game, both common to all players. The challengers will always receive a negative payoff from accepting the hegemony, while the hegemon instead benefits from it. A deterrence equilibrium is a pure strategy sequential equilibrium in which a challenge in period 1 is fought by the hegemon and where the challenger at time 3 accepts the hegemony, or in which the first challenger acquiesces on the correct belief that the any type of hegemon would fight off the equilibrium path at time 2.

The model is used to recreate the situation where a hegemon tries to mitigate the complexities of long-distance trade such as inefficient contracting and insecure property rights through military

actions. The model is further described in the following section and the considerations behind the unlimited resource constraint and the different players' perspectives on the payoffs from the current hegemony are further explained in section five.

4. Model

4.1 List of abbreviations

Players

Hegemon	H ($H_S = Strong\ type,\ H_W = Weak\ type$)
Challenger	$C_i,\ i = 1,\ 2$

Actions available to the hegemon

Acquiesce	A
Fight	F

Actions available to the challenger

Challenge	In
Not challenge	Out

Payoffs

Cost of conflict	k
Value at stake	t

Beliefs about the hegemon's type

Probability of strong	$\pi,\ \pi \in (0,\ 1)$
Probability of weak	$1 - \pi$
Information set	$h_i,\ i = 1,\ 2,\ 3$
Belief at information set i	$\mu_i,\ i = 1,\ 2,\ 3$

4.2 Basic lineup of the model without resource constraints

The hegemon (H) has extended trade into regions characterized by insecure exchange, and in the time periods that follows, the challengers (C), which can be seen as the regional powers in the region, have the ability to challenge (denoted In), which results in a cost for the hegemon, or stay out of it by cooperating in the trade taking place (denoted Out). The action set available to the challengers is thus $\{In, Out\}$. In can be thought of as an appropriation of H's assets that are held abroad, enforcing illegal tolls, extending C's territorial waters, or other measures that increase the cost for the hegemon to engage in international trade, whereas Out can be seen as abstaining from these practices, thus preserving status quo. If C chooses Out, H will do nothing, but if C chooses In, H faces the choice of either acquiescing (A) or fighting (F). The action set available to the hegemon is thus $\{F, A\}$.

The hegemon H can be of two different types, either "strong" (H_S) or "weak" (H_W). This type is assumed to be exogenously drawn from "nature", and only known to H. It is common knowledge that the probability of H_S is π, where $\pi \in (0, 1)$. Inference about the hegemon's true type can therefore only be done from the observation of past information sets h_i, $i = 1, 2, 3$, where the belief at each information set is denoted μ_i. Let the realization of $\{In, F\}$ at time 2 provide information set h_1, $\{In, A\}$ provide information set h_2, and $\{Out, \bullet\}$ provide information set h_3, so that $\mu_1 = \pi, \mu_2 = 0, \mu_3 = \pi$.

If C chooses Out he pays t to H, where $t \in (0, \infty)$ is exogenously fixed and the same for each local player. t here represents the benefits obtained by H from trading in a secure and cooperative environment, and the loss from not choosing In for C, which could, for example, be negative local effects from globalization or the opportunity cost from not appropriating goods in the insecure environment.

Should C instead choose In and H respond with A, realizing $\{In, A\}$, both players will get 0. H responding with F to the entry, realizing $\{In, F\}$, will instead cost k $(k > 0)$ to both H and C. In this case t is divided between the players with H getting t if he is strong and nothing if he is weak, so that H_S gets $t - k$ and H_W gets $-k$. C will in turn get $-t - k$ from fighting H_W and $-k$ from H_W.

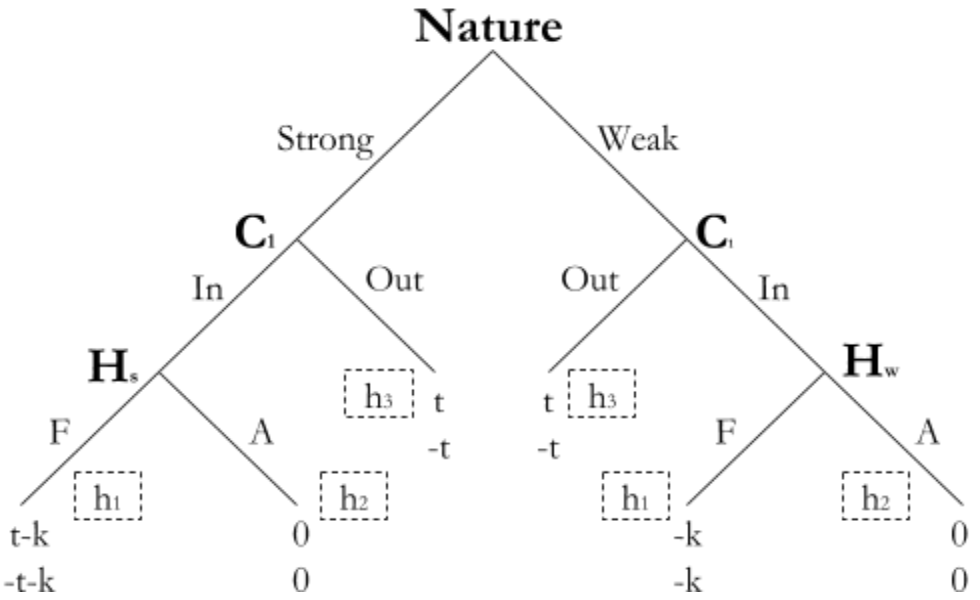

Figure 1. Depiction of the game in time 1 and 2, with H's type given exogenously by "nature" in the beginning. The payoffs are given first for the hegemon and second for the challenger, the different information sets are shown in the dotted boxes.

The game takes place in four periods where the first challenger C_1 chooses from the action set $\{In, Out\}$ at time 1 followed by the hegemon's response from $\{F, A\}$ at time 2, with period 3 and 4 being played in a same manner by C_2 and H.

In any equilibrium, H_S will fight at time 4 if $t > k$, while H_W always acquiesces at time 4. At time 2 there are, however, equilibria in which even H_W fights to preserve its reputation. A deterrence equilibrium (DE) is a pure strategy sequential equilibrium in which either:

1) C_1 challenges with both H_S and H_W responding with F at time 2, followed by C_2 playing Out at time 3.
2) C_1 stays out at time 1 on the correct belief that off the equilibrium path both H_S and H_W would fight at time 2.

In the case of 1), an investment in reputation must be made. In 2), the correct belief that any H would fight at time 2 deters the challenger. In the second case fighting challenges is an off the equilibrium path event, whereas it is an on-the-equilibrium-path event in the first case. Any pure strategy sequential equilibrium that includes the play in 1) or 2) is a DE.

Proposition 1: In a game without resource constraints:

A) If the stakes of the game, t, are neither too low nor too high relative to the cost of fighting, k, and π is sufficiently high, $k \leq t \leq \frac{\pi k}{1-\pi}$, at least one deterrence equilibrium exists. If $t > \frac{\pi k}{1-\pi}$, no DE exists.

B) A partial deterrence equilibrium may exist even when $t > \frac{\pi k}{1-\pi}$. If it does exist, the frequency $p_w = \frac{\pi}{1-\pi} \cdot \frac{k}{t}$ with which H_W fight C_1's challenge in order to deter C_2 is lower the higher the stakes are.

Part A) of proposition 1 provides the conditions that we intend to analyze further on in the paper to evaluate the real world applicability of deterrence in the context of international trade, and we will therefore now provide proofs of the proposition 1.A.

In a DE both types of hegemons will fight, on or off the equilibrium path, at time 2 if faced with In, giving C_2 the belief $\mu_1 = \pi$. Not fighting at time 2 would instead give C_2 the belief $\mu_2 = 0$. This would lead C_2 to challenge at time 3 with certainty so that H_W ends up acquiescing again with $payoff_{H_W, A} = 0 + 0$, and H_S playing F with $payoff_{H_S, A} = 0 + t - k$. Fighting the initial challenge would instead yield $payoff_{H_W, F} = -k + t$ and $payoff_{H_S, F} = t - k + t$ respectively.

H_W will fight at time 2 if $payoff_{H_W, A} \leq payoff_{H_W, F} \Rightarrow 0 + 0 \leq t - k \Rightarrow t \geq k$.
H_S will fight at time 2 if $payoff_{H_S, A} \leq payoff_{H_S, F} \Rightarrow t - k \leq 2t - k \Rightarrow t \geq 0$.
If $t < k$, even the strong hegemon acquiesces at time 4, and C_2 therefore challenges at time 3 so that there can be no DE.

C_1 knows that any type of hegemon, in a DE, will fight at time 2, giving an expected payoff of $\pi(-t-k) + (1-\pi)(-k)$. C_1 will therefore stay out if $payoff_{C_1, In} \leq payoff_{C_2, Out} \Rightarrow$
$\pi(-t-k) + (1-\pi)(-k) \leq -t \Rightarrow -\pi t - \pi k - k + \pi k \leq -t \Rightarrow \pi t + k \geq t \Rightarrow t \leq \frac{k}{1-\pi}$.

C_2, on the other hand, knows that only the strong hegemon will fight at time 4, giving him an expected payoff from challenging of $\pi(-t-k) + (1-\pi) \cdot 0 \Rightarrow \pi(-t-k)$. C_2 will therefore abstain from challenging the hegemon if $payoff_{C_2, In} \leq payoff_{C_2, Out} \Rightarrow \pi(-t-k) \leq -t \Rightarrow$
$-\pi t - \pi k \leq -t \Rightarrow (1-\pi)t \leq \pi k \Rightarrow t \leq \frac{\pi k}{1-\pi}$.

This gives the condition stated in proposition 1.A, $k \leq t \leq \frac{\pi k}{1-\pi}$, for a DE to exist. Since $\pi \in (0,\ 1)$, $\frac{k}{1-\pi} > \frac{\pi k}{1-\pi}$ will be true. This gives $k \leq t \leq \frac{\pi k}{1-\pi} < \frac{k}{1-\pi}$, so that C_1 playing out is the only deterrence equilibrium in the game.

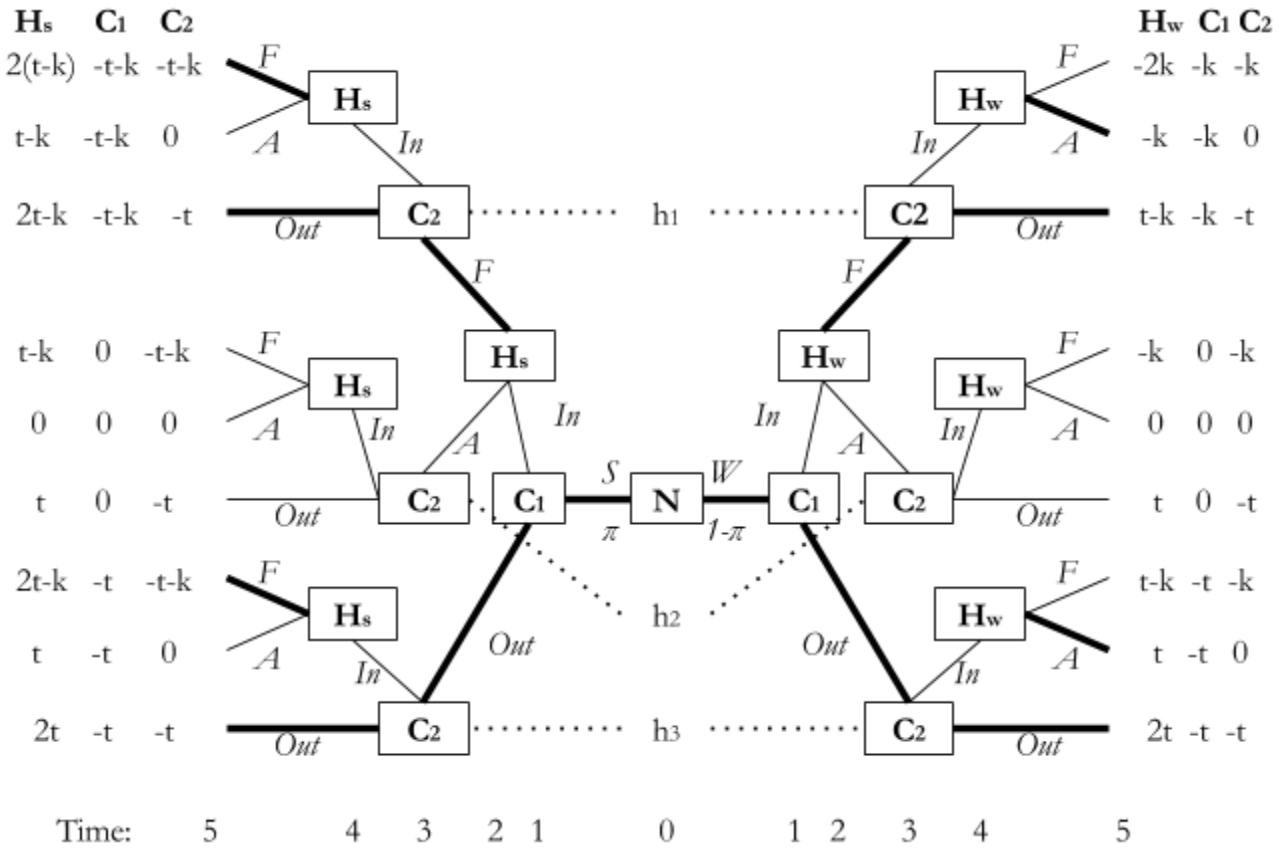

Figure 2. The complete game tree of a game with unlimited resources. The deterrence equilibria and the off equilibrium path events are marked with bold lines.

Part B) of proposition 1, the partial deterrence equilibrium (PDE) will not be the focus of this paper and is only shown here to provide some insight on the game when the criteria for a DE are not met. Proof of this equilibrium will be provided in the appendix, or in Treisman (2004). A PDE is a mixed strategy sequential equilibrium that occurs when either:

1) C_1 challenges, both types of H fight in time 2 with positive probabilities $p_s \leq 1$ for the strong type and $p_w < 1$ for the weak type, and C_2 play Out at time 3 with positive probability.
2) C_1 stays out because of its correct belief that, off the equilibrium path, any H will fight at time 2 with enough probability to make Out preferable to In.

The model shows that for moderate stakes, an equilibrium exists in which even a weak hegemon will fight the first challenge to preserve its reputation, something that deters the first challenger from entry. For higher stakes, the weak hegemon only sometimes fights the first challenge, and less frequently so as the stakes get higher. If stakes are too high, deterrence will thus not be effective as the weak hegemon will fight too infrequently due to cost concerns. If the stakes are too low, on the other hand, no hegemon will bother to fight for its reputation as it is not worth the cost.

4.3 Deterrence and appeasement under limited resources

In a game where the hegemon operates with limited enforcement resources, the rational approach may change if the challengers are strong enough to, to some degree, deplete the hegemon's strength. Suppose that H_S fights C_1, thus getting t units of utility like before. The fight has, however, left H_S weakened and when faced with C_2's challenge the hegemon will only manage to extract t/α units of utility, where α measures how severely he is weakened and $\alpha > 1$. As shown by Treisman (2004), appeasement, instead of fighting for reputation, is here rational under certain conditions.

Proposition 2: In the game with resource constraints, a deterrence equilibrium only exist if $\alpha k \leq t \leq \frac{\alpha k \pi}{\alpha - \pi}$. A partial deterrence equilibrium only exists if $\alpha k \leq t \leq \frac{\alpha k}{\alpha - 1}$.

Proposition 3: In this game, an appeasement equilibrium only exists if $k \leq t \leq min\left[2\alpha k, \frac{k\pi}{1-\pi}\right]$.

The case with limited resources is, however, not the focus of our paper as it is not as well suited for answering our research question. For further proofs see appendix, and also Treisman (2004), whose paper focuses on these types of equilibriums.

4.4 Example of a deterrence equilibrium without resource constraints

We will here, to help the reader's intuition, illustrate a game in which there is a deterrence equilibrium, using an arbitrary set of payoffs and probabilities. Suppose that only the hegemon knows its true type, but that it is common knowledge that the hegemon is strong, H_S, with probability $\pi = 0.8$ and weak, H_W, with probability $1 - \pi = 0.2$. The cost of conflict for all players is $k = 1$ and the value at stake is $t = 3$ so that $\frac{\pi k}{1-\pi} = 4$, thus satisfying $k \leq t \leq \frac{\pi k}{1-\pi} < \frac{k}{1-\pi}$.

The first challenger, C_1, plays at time 1 with the choice to either challenge or stay out, $\{In, Out\}$. By staying out, C_1 has to transfer a utility of $t = 3$ to H so that he gets the payoff 3, leaving C_1 with a payoff of -3. Contemplating whether In may be a better choice, C_1 observes that any hegemon, regardless if he is strong or weak, will respond with F to a challenge. Fighting H_s will incur a cost of $-t-k = -4$ to C_1, while fighting H_W only costs $-k = -1$. The challenger's expected payoff from playing In is therefore $\pi(-t-k) + (1-\pi)(-k) \Rightarrow$ $0.8(-3-1) + (0.2)(-1) = -3.4$. Since $-3 > -3.4$, choosing Out maximizes C_1's utility given the available information, and the hegemon is thus not challenged.

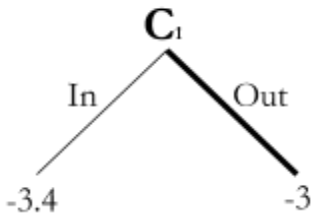

Figure 3. The first challenger decides how to play based on his expected payoffs. In this case, challenging the hegemon leaves C_1 worse off than accepting his authority, and C_1 plays Out.

Had C_1 played differently, for some reason ignoring the loss of utility from In, both H_s and H_w would, as mentioned above, have fought his challenge, due to anticipating a rational C_2. By acquiescing at time 2, the hegemon would face a C_2 with a belief μ_i of H's strength based on information set h_2, so that $\mu_2 = 0$, meaning a certain challenge as C_2's expected payoff

$\pi(-t-k) = 0(-3-1) = 0$ from playing In is better than the payoff -3 from playing Out. By playing F at time 2, the hegemon knows that C_2 will judge the probability of H's strength at $\pi = 0.8$, making C_2's expected payoff from playing In -3.2 compared to the payoff of -3 from playing Out, thus deterring the rational C_2. As evident, fighting will therefore occur off the equilibrium path as the response to a challenge at time 2.

With C_1 having played Out, C_2 now makes his move based on information set h_3 with belief $\mu_3 = \pi$. A strong hegemon would respond to In at time 3 by playing F at time 4, yielding him $t-k = 2$ instead of 0 that would be the result from acquiescing at time 4. On the contrary, the weak hegemon would play A at time 4 if challenged, preferring a payoff of 0 to $-k$ from fighting. As with C_1, C_2 now faces the choice of an expected payoff of -3.2 by playing In, or -3 by playing Out, thus choosing to not challenge the hegemon.

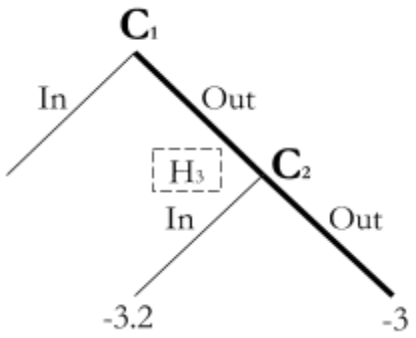

Figure 4. The second challenger makes his decision based on information set h_3, believing in a strong hegemon with an unchanged probability π. C_2's expected payoffs are therefore the same as C_1's, and he too chooses to play Out.

In this numerical example meant to further illustrate the general model presented in section 4.1, a deterrence equilibrium is observed, where the hegemon obtains the maximum utility possible in the game, $2t = 6$, at the expense of the regional challengers C_1 and C_2, each losing -3 from accepting the hegemony.

5. Analysis

Through the introduction of information asymmetry and a subsequent Harsanyi transformation (see section 2.2) into imperfect information, reputation effects have been shown, in a simplified setting, building on Kreps and Wilson (1982), Milgrom and Roberts (1982) and Treisman (2004), to result in deterrence equilibria. This sheds light on the observed behavior in the long-distance trade partners of the U.S. and provides a rationalization for the short-term costs that safeguarding military operations result in. It is the informational asymmetry that causes entrants to predict future behavior based on past actions, and this in turn creates incentives for the hegemon to establish a reputation that can provide a final payoff which is large enough for it be acceptable to incur the short-term costs from fighting.

In our analysis we will show through a number of current and historical examples how the cost of enforcement (k) and the stakes of the game (t) could potentially be such that a great power, of sufficient reputation, engaged in international trade can end up in a deterrence equilibrium with regards to its challengers. The analysis is not intended to be an extensive empirical investigation, but is rather meant to shed light on the plausibility of a deterrence equilibrium being present in real situations.

5.1 Deterrence without resource constraints

In the context of our paper, H can be considered to be acting without notable resource constraints, as there is a significant difference in the military capabilities of H and C. Even though the model shows that a deterrence equilibrium can exist under limited resources at a sufficiently small α, we have chosen to assume no resource constraints at all as it better reflects a reality where the major power enjoys a significant *overcapacity* in enforcement relative to its opponents. A skirmish with a small power may of course do some damage to the hegemon's fighting force, but there is no diminished capability to engage the next challenger as only a small fraction of the total military resources are used against both of the challengers combined. Facing opponents of more equal military strength changes this, as shown in section 4.3, when the hegemon must take into account

his credibility towards a second powerful challenger after having a significant share of his own forces depleted by the first challenger at time 2, making appeasement the rational response under these circumstances. This is, however, not something that we will explore further in our analysis.

Current U.S. military doctrine states (U.S. Department of Defense 2012) that U.S. forces, even when committed to a large-scale operation in one region, will be capable of denying the objectives of - or imposing unacceptable costs to - an opportunistic aggressor in other regions. There are several nations in the world with the military spending and power projection capabilities required to sustain at least a regional hegemony. The most notable is the U.S. with a military expenditure that is around 37% of the total world military expenditure, but also China (11% of world military expenditure), Russia (5%), and possibly the U.K., France and India with 3.3%, 3.5% and 2.7% respectively (SIPRI 2014). By moving further back in time other actors that arguably have been in similar positions appear, consider for example the Roman empire and the vast military capacity it obtained in comparison to its contemporaries.

5.2 The challenger's perspective on the prevalent hegemony

In the model, the challengers face a cost $-t$ even from staying out. Trade is not a zero-sum game where one party loses and the other wins, but nevertheless one way of looking at it is that new trade expansion can lead to drastic changes such as imports forcing local factories to close - creating substantial political backlash. As Rodrik (2003) argues, globalization is by its nature disruptive, and things that are disruptive are also destabilizing and result in winners and losers. One poignant example of dissatisfaction with the distributive effects of world "order" is The New International Economic Order (NIEO), in which a group consisting of many developing countries - the G77 movement - in Africa, South America, Asia and the Middle East put forth a set of proposals meant to improve their terms of trade in relation to the current "hegemons" (Lake 2010). The proposal addressed, among many things, political regulation of international trade and finance, but was, unsurprisingly, ultimately unsuccessful and the dominant "order" ended up being the Washington Consensus.

5.3 Costs, stakes and reputation

The model we use explain the actions of a hegemon and its challengers based on the cost of engaging in conflict (k), the stakes of the game (t), and the reputation of the hegemon (π).

Large-scale conflict is an extremely costly endeavor, with the financial costs of the recent war in Iraq estimated to be $3.1 trillion (Watson Institute for International Studies 2013). Smaller operations need not be as financially burdening, however. The numerous freedom of navigation (FON) operations undertaken by the U.S. Navy (U.S. Department of Defense 2014) normally involve a small naval task force that navigate through contested waters as a response to perceived violations of the UN Convention on the Law of the Sea. The U.S. conducted at least 23 of these operations in 2013, and at least 22 the year before. Even in the most extensive FON operations yet undertaken, the Gulf of Sidra incident of 1986 and the American interventions during the Iran-Iraq war, the battle damages are comparatively small. The U.S. Navy, for example, values the damage on the USS Stark from Iraqi missiles in 1987 to $142 million (U.S. Department of Defense 1987), a significant but not devastating cost to most military powers. The cost of enforcement, k, can thus be relatively low when the conflict is limited to smaller interventions, as opposed to the almost unlimited cost of total war.

The stakes of the game, t, is here meant to be widely interpreted and can be thought of as any gains from trade, security or otherwise that the hegemon enjoys and, conversely, the cost of being subject to the hegemony that the potential challenger state has to bear. Sequeira and Djankov (2008) have, as previously mentioned in section 1, found strong evidence that corruption in African ports increase shipping costs by 14%, with the costs covering, among others, the protection of the cargo. With U.S. exports to Africa and the Middle East totaling more than US$100 billion (WTO 2013), it is clear that even regional inefficiencies like these can amount to large sums of money for economies far removed from the actual areas suffering from corruption. Other forms of regional trade inefficiencies that the hegemon may desire to minimize are, for example, terrorism, excessive tolls, piracy, and military interventions by local powers. The case of piracy is interesting in that it usually takes place in narrow, but important, shipping lanes such as the Malacca Strait or the Gulf

of Aden, where US$ 1 trillion of trade pass yearly (The World Bank 2014). Piracy is also the cause of substantial costs for the different actors of international trade, with The World Bank estimating a yearly cost of US$18 billion from Somali piracy, including higher insurance premiums, costs for self-defense, ransom money, military interventions, rerouting, and loss of trade in the region.

Another indicator of the value at stake in our game of hegemony is the risk of appropriation of assets held abroad by the hegemon. These assets can be direct investments in foreign countries, goods in transit at sea, oil pipelines, or something else. A notable example is the Egyptian nationalization of the Suez canal in 1956, and the subsequent Anglo-French-Israeli military retribution. Considering that 7.5% of today's total oceanic trade pass through the Suez canal (World Shipping Council 2014), with the 1955 figure being even higher at 13% (The Economic Weekly, 1957), it is not difficult to see why the stakes are high for both sides. On the one hand there is the Western European need for shipping of goods, primarily oil from the Middle East, through the canal which would otherwise have to travel the costly route around Africa. On the other hand there is the Egyptian disgruntlement over how a few Western European powers enjoy most of the benefit from the vitally important canal, and the realization that the Egyptian nation could benefit more if the canal was not controlled by European interests. In the context of our model, t is thus very large for both players - the hegemon benefitting t from inexpensive trade enabled by its deterrent, and the challenger paying the alternative cost $-t$ by accepting the hegemony.

Therefore, if certain conditions are met it is possible that $k \leq t$ for a real event involving a hegemon and its challengers, and if $k \leq t \leq \frac{k\pi}{1-\pi}$ at least one (off the equilibrium path) deterrence equilibrium exists. For this to happen the utility at stake in the conflict must be equal to or greater than the cost of carrying out said conflict, while at the same time at most equal to the cost of accepting the hegemony for the challenger. This relationship could potentially be true in a U.S. FON operation with the goal of keeping the Strait of Hormuz open for oil exports. In this case the conflict is limited in scale and the economic stakes are high for both parties, the U.S. benefitting from unrestricted strategic access to an important oil hub and Iran wishing to be freed from economic sanctions currently burdening its economy. Note that the different challengers C_1 and

C_2 need not be different entities, but may as well be constituted by, for example, one nation state where the decision makers have changed, compare pre- and post-revolution Iran, between time 1 and time 3. If the U.S. enters this game with a large enough probability of being the strong type, π, a deterrence equilibrium will be present where other states in the region, or a later Iranian regime, is discouraged from interfering with U.S. interests. This yields the hegemon $2t$ if all challenges are deterred or , depending on its type, $2t-k$ or $t-k$ if not, while the regional powers bear a collective $-2t$ in the event of successful deterrence, and either $-2t-k$ or $-k-t$ in the event of conflict. The terms *strong* and *weak* should not be literally interpreted as military strength, in which case the U.S. would have a π very close to 1, but rather as the capability to fight and achieve the objectives of the conflict, which is also dependent on such factors as the political will to go the length required to secure the objectives, thus even very strong military actors can be constrained by factors beyond military capabilities. Even if $t > \frac{k\pi}{1-\pi}$, there may exist a partial deterrence equilibrium (PDE). In this case challenge and fight happens in time 1-2 with positive probabilities, and C_2 play Out at time 3 with positive probability, or C_1 stays out at time 1 because of its correct belief that, off the equilibrium path, any H will fight at time 2 with enough probability to make Out preferable to In. In PDE, the frequency with which H_W fights C_1's challenge in order to deter C_2 is given by $p_w = \frac{\pi}{1-\pi} \cdot \frac{k}{t}$, so that a higher π increases the probability of fight while higher stakes, t, decreases it.

6. Concluding remarks

The research question we approached in this paper is why a hegemon would be willing to incur short-term costs from conflicts that do not pose a direct military threat, and if this can be explained by extending the perspective to a long-term view of insecure trade environments. In order to examine this we have extended the chain store game beyond its standard applicability in describing a monopolist facing new entrants. Our paper encompasses a conflict situation in which a hegemon tries to economize on upholding beneficial trade in an insecure environment by building reputation effects through costly short-term military interventions on an interconnected global market in which regional powers draw inference from observed past behavior.

We have strived to illustrate the link between the evolution of international long-distance trade into regions with institutionally very different environments with the inherent complexity in its safeguarding, and the possibilities for opportunistic (or negligent) behavior that the regional powers face, and how efficient upkeeping can require short-term costs for a hegemon wishing to preserve with expansive trade while economizing on its upkeeping.

The notion of reputation has been widely applied to different situations, most notably to the field of industrial organization. The possible applications of reputation models are, however, far beyond industrial organization and conflict, as long as an interaction contains informational asymmetry and uncertainty - which is the case in most situations - inference about past behavior as a predictive tool for the future plays an important part.

Results in reputational models can be sensitive to variations in different parameter values, and if their predictive power is to be improved, new insights from neighboring fields would have to be incorporated. For example, the assumption that the player's know their exact payoffs is a rather strong assumption. The model, in its simplicity, also fails to capture how the payoffs may not be the same for all players in a real situation. The discrepancy between the rationally predicted behavior and actual empirically observed play in games is widely recognized in the economics literature in general, and the models are continuously refined. It is also undeniably true that conflicts are complex, encompassing many different interests and decision makers, and also heavily situation-dependent. Battigalli and Watson (1997) do however show that reputation effects can hold with less than the equilibrium notion. Sorin (1999) raises the potential issue of how reputation effects can fail with a large enough discount factor for the challengers.

Further studies and possible extensions include alliance formations (see Crawford 2011 and Crescenzi et al. 2011), more sophisticated modeling of beliefs and tacit assumptions (see Axelrod 1985), the role of sanctions, empirical tests, non-arbitrary prior reputations (see Battigalli and Watson 1997), and other methods in the general spirit of better capturing the actual behavior.

Extensive empirical case studies lie beyond the scope of this paper, but we wish to emphasize that several of the case studies done in the field of political science and international relations with regards to reputation have focused their attention mainly on cases of outright large-scale wars. These are conflicts that touch upon the fundamental *raison d'état* and therefore are of such importance that acquiescing may not be a politically viable option. Our paper instead discusses how the enforcement of trade rules and stability in insecure environments presents no direct threat to a hegemonic state's safety, but a very interesting cost-benefit evaluation of the long-term trade-off between enforcement and cooperation. The cost from the hegemon's perspective is rather what potential spillover-effects that might occur and how other states might interpret the hegemon's actions and adjust their expectation for future behavior.

Creating and utilizing multilateral institutions that maintain secure environments and provide transparency with regards to appropriative measures and corruption should lie in the interest of a hegemon. It is however undeniably difficult and the continued failure to efficiently bargain without resorting to conflict, especially in insecure environments, suggest that it is an area worthy of continued studies. Yet there is no denying that in today's world much trade and cooperation between, sometimes fundamentally different, states is at hand. Indeed, interstate cooperation is at an unprecedented level. Whether this is due to what occurs "in the shadow of conflict" which has been the focus of this paper, in the light of institutional cooperation, or through a combination of both, it is important for those that every day are faced with the consequences of conflict.

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9. Appendix

9.1 Figure 1A

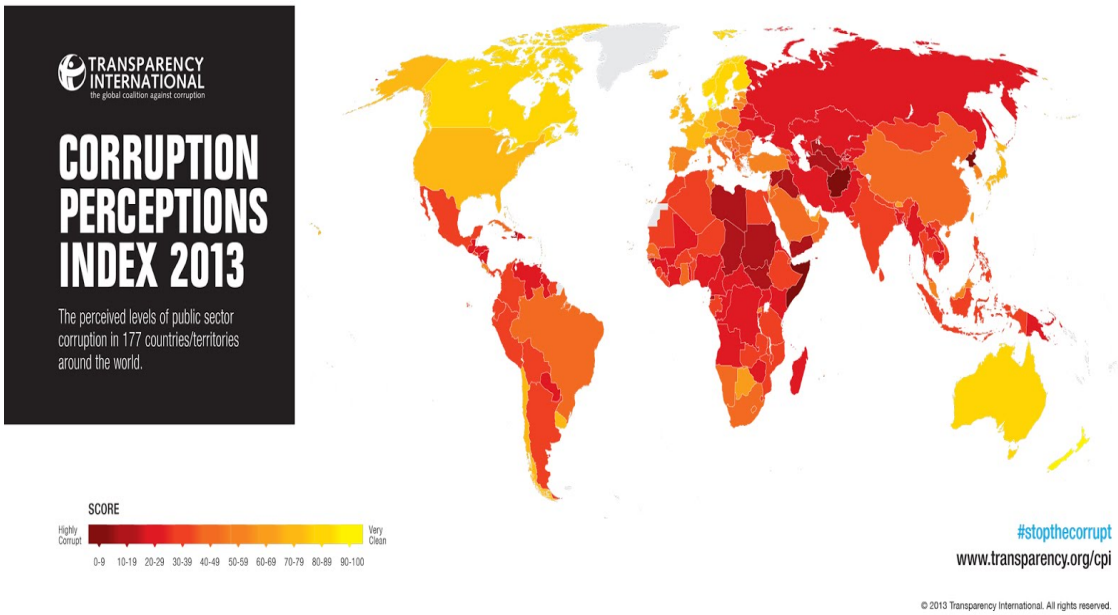

Figure 1A. Corruption Perceptions Index 2013.© Transparency International.

9.2 Further proofs of proposition 1.B.

A partial deterrence equilibrium may exist even when $t > \frac{\pi k}{1-\pi}$. A PDE is a mixed strategy sequential equilibrium that occurs when either:

1) C_1 challenges, both types of H fight in time 2 with positive probabilities $p_s \leq 1$ for the strong type and $p_w < 1$ for the weak type, and C_2 play Out at time 3 with positive probability.
2) C_1 stays out because of its correct belief that, off the equilibrium path, any H will fight at time 2 with enough probability to make Out preferable to In.

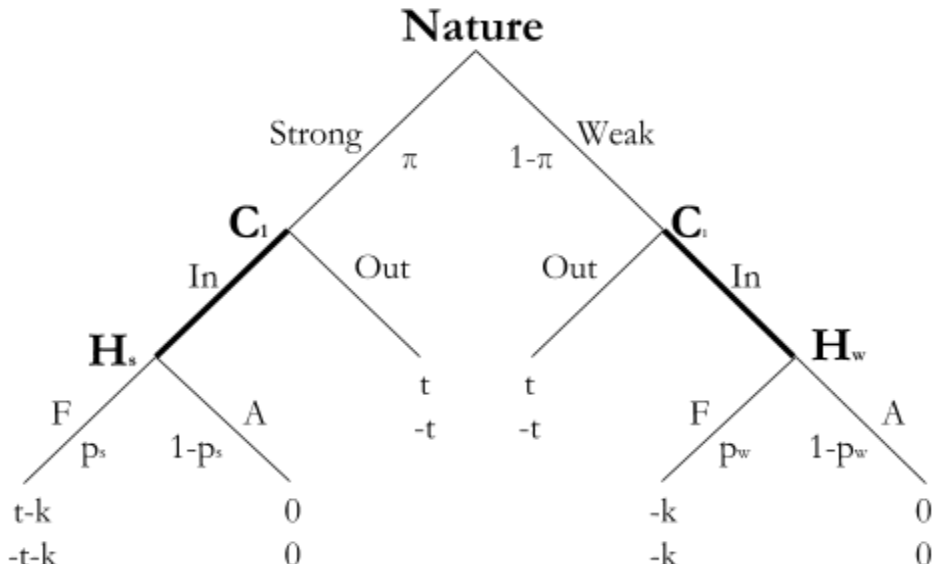

Figure 2A. Depiction of game tree at time 1 and 2. Equilibrium paths bolded.

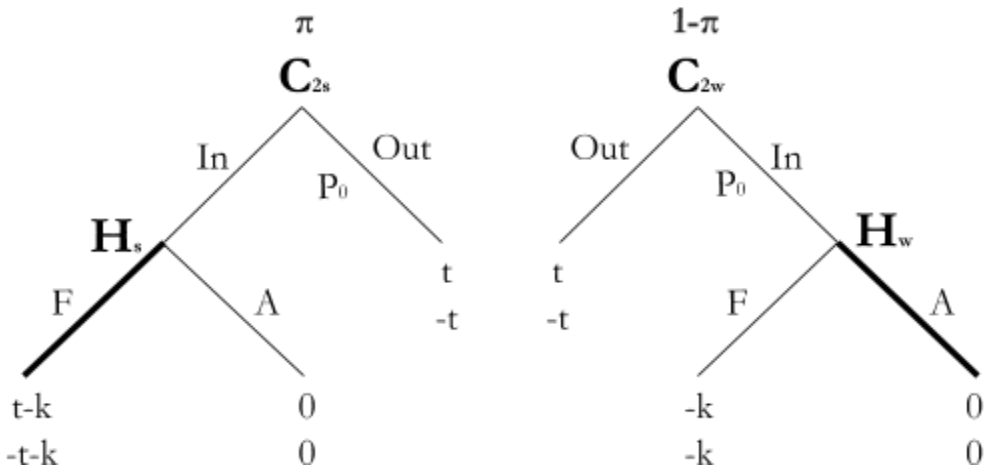

Figure 3A. Depiction of the game at time 3 and 4, with off equilibrium path events marked in bold lines.

$$Prob\ (H_S \mid F) = \frac{Prob\ (H_s \cap F)}{Prob\ (F)} = \frac{\pi p_s}{\pi p_s + (1-\pi)p_w}$$

$$Prob\ (H_W \mid F) = \frac{Prob\ (H_w \cap F)}{Prob\ (F)} = \frac{(1-\pi)p_w}{\pi p_s + (1-\pi)p_w}$$

$$Prob\ (H_S \mid A) = \frac{Prob(H_s \cap A)}{Prob(A)} = \frac{\pi(1-p_s)}{\pi(1-p_s)+(1-\pi)(1-p_w)} = 0$$

$$Prob\ (H_W \mid A) = \frac{Prob(H_w \cap A)}{Prob(A)} = \frac{(1-\pi)(1-p_w)}{\pi(1-p_s)+(1-\pi)(1-p_w)} = 1$$

We test an equilibrium where C_1 chooses In

H_S fights with probability $p_s = 1$

H_W fights with probability $p_w < 1$

C_2 chooses out with probability $p_0 < 1$ if F, and In if A.

If A, then C_2 knows that H is weak

C_2 chooses In and sets payoff $= 0$

If F, then C_2 believes:

$$Prob\,(H_S \mid F) = \frac{\pi}{\pi + (1-\pi)p_w}$$

$$Prob(H_W \mid F) = \frac{(1-\pi)p_w}{\pi+(1-\pi)p_w}$$

$$\pi_{C_2,\,In} = \frac{\pi}{\pi+(1-\pi)p_w}(-t-k) + \frac{(1-\pi)p_w}{\pi+(1-\pi)p_w} \cdot 0$$

$$\pi_{C_2,\,Out} = -t$$

$$-t = \frac{\pi}{\pi+(1-\pi)p_w}(-t-k) \Rightarrow \frac{\pi}{\pi+(1-\pi)\,p_w}(t+k) = t$$

$$\frac{\pi k}{\pi+(1-\pi)p_w} = t\left[1 - \frac{\pi}{\pi+(1-\pi)p_w}\right] = t\frac{(1-\pi)p_w}{\pi+(1-\pi)p_w}$$

$$\frac{\pi k}{(1-\pi)p_w} = t$$

$$p_w = \frac{\pi k}{(1-\pi)t}$$

9.3 Proof of proposition 2 and 3

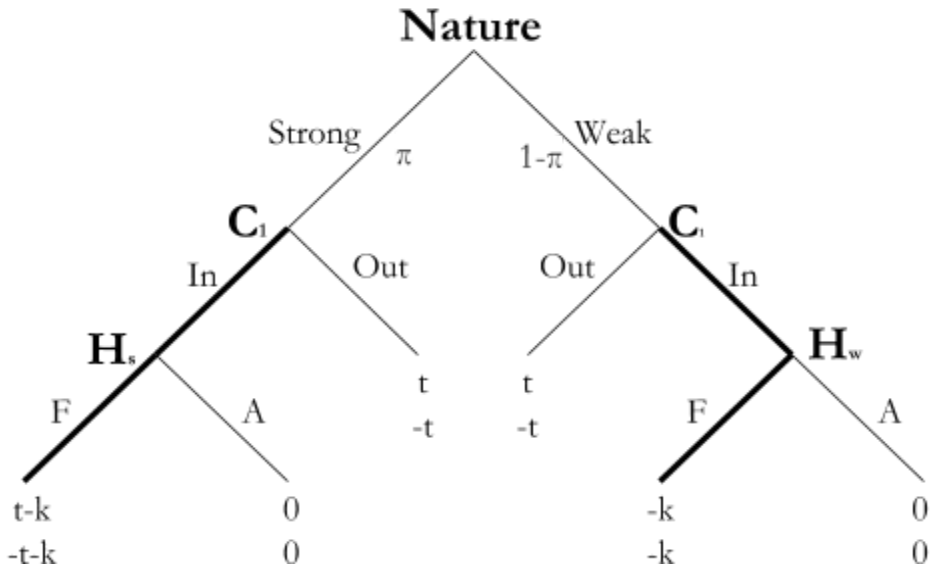

Figure 4A. Depiction of the game at time 1 and 2, equilibrium paths bolded.

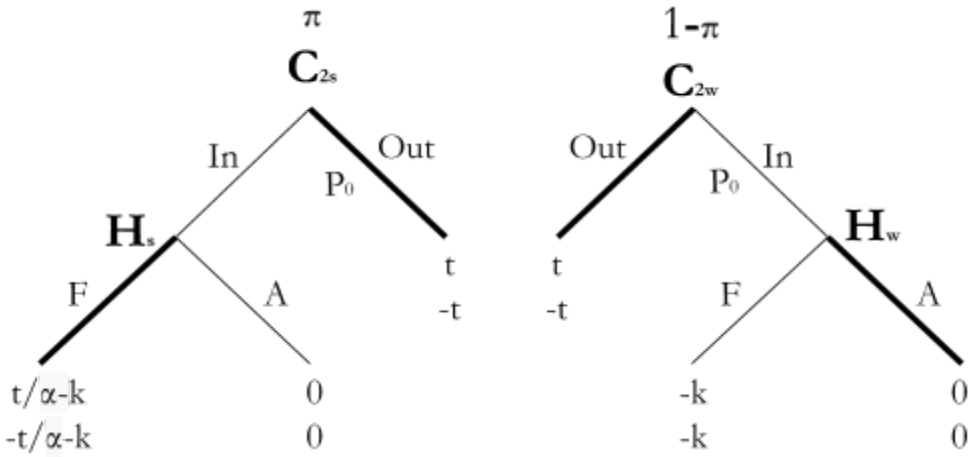

Figure 5A. Depiction of the game tree at time 3 and 4, equilibrium paths and off path events are shown with bolded lines.

$payoff_{C_2,\,Out} \geq payoff_{C_2,\,In} \;\Rightarrow\; -t \geq \pi\left(-\frac{t}{\alpha} - k\right) + (1-\pi)0$

$\pi\left(\frac{t}{\alpha} + k\right) \geq t$

$\pi k \geq (1 - \frac{\pi}{\alpha})t$

$\frac{\pi k}{1-\frac{\pi}{\alpha}} \geq t$

$\frac{\alpha\pi k}{\alpha-\pi} \geq t$

H_w fights if

$payoff_{H_W,\,F} \geq payoff_{H_W,\,A} \;\Rightarrow\; t - k \geq 0 + 0 \;\Rightarrow\; t \geq k$

H_s at stage 4 chooses F if $\frac{t}{\alpha} - k \geq 0 \;\Rightarrow\; \frac{t}{a} \geq k \;\Rightarrow\; t \geq \alpha k$ where $\alpha > 1$

C_1 chooses Out if

$payoff_{C_1,\,Out} \geq payoff_{C_1,\,In} \;\Rightarrow\; -t \geq \pi(-t-k) + (1-\pi)(-k)$

$\pi(t+k) + (1-\pi)k \geq t \;\Rightarrow\; \pi t + k \geq t \;\Rightarrow\; k \geq t(1-\pi) \;\Rightarrow\; \frac{k}{1-\pi} \geq t$

This gives the condition $\alpha k \leq t \leq \frac{\alpha k \pi}{\alpha - \pi}$ which must be true for a deterrence equilibrium to exist under limited resources.