Enforcing cooperation among medieval merchants: The Maghribi traders revisited

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Abstract

We revisit Greif's (1993) analysis of trade between the 11th-century Maghribi traders and present two different models which bring into play, in an essential way, historical features of the Maghribi's organization which had no role in Greif's own analysis. Our reformulation of the Maghribi's "punishment strategies" incorporates principal components of their actual historical practice and explains why they may have been necessary to sustain cooperation, especially in the presence of uncertainty or imperfect information. We also model "formal friendships," or trade through bilateral and multilateral partnerships, and predict the Maghribi's practice of providing agency services without pecuniary compensation. We are thus able to provide a richer and more accurate picture of how that organization facilitated trade between widely-dispersed traders in the absence of a reliable legal system to enforce merchant contracts.

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"The goods sent by you arrived safely through God's grace...." (Joseph Taherti, a Maghribi trader, 1063 AD)

"Before setting out eastward to India, Joseph traveled westward to Tunisia and collected goods from other merchants in order to trade with them on his way. His trip to India, however, was marred by shipwreck and other misfortunes involving great losses. As is natural, he faced many lawsuits on his return." (Report of a trip of Joseph Lebdi, a Maghribi trader, 1097 AD)

1 Introduction

Greif's (1993) path-breaking study of trade amongst the Maghribi traders (see also Greif, 1989) represents an early attempt to apply formal game-theoretic tools to the study of economic history. It is therefore both highly regarded and deservedly influential. The purpose of this paper is to point to a number of lacunae in Greif's analysis which make it worth revisiting. Doing so leads us to develop two different models of Maghribi trade relationships which bring into play - in an essential way - historical features of the Maghribi's organization which had no role in Greif's own analysis. We are thus able to provide a richer and more accurate picture of how that organization facilitated trade amongst widely-dispersed traders in the absence of a reliable legal system to enforce merchant contracts.

Jewish Maghribi traders were engaged in long-distance trade all over the Muslim Mediterranean in the 10th to 12th centuries (Greif, 1989, 1993; Goitein, 1973). It was efficient to operate through overseas agents rather than having each merchant travel abroad with his goods.[1] Agency relations enabled some merchants to operate as sedentary traders, thus saving the cost and risk of sea journeys, and enabled traveling merchants to rely on agents to handle their affairs in their absence. But because agents could cheat while handling a merchant's capital, to be employed they had to be able to commit *ex ante* to being honest *ex post*, after the goods were sent to them. Without

[1] Agents provided merchants with many trade-related services, including loading and unloading ships; paying customs, bribes, and transportation fees; storing the goods; transferring the goods to the market; and deciding when, how, and to whom to sell the goods, and at what price. Greif (2006), Chapter 3.

an institution to support honesty, merchants would have anticipated opportunistic behavior and refused to hire agents. Mutually beneficial exchanges would not have occurred.

Greif's analysis resolves this commitment problem by positing a "multilateral reputation mechanism," based on a review of the historical evidence.[2] In his model, an agent who embezzles the goods of any Maghribi merchant is branded a "cheater" and not employed thereafter by any merchant (the "collective" or "multilateral" punishment strategy). Amongst the Maghribis, the collective punishment of cheating agents was made feasible by the transmission of detailed information between merchants on agents' past behavior. Further, merchants were motivated not to hire an agent who had cheated (i.e. to participate in the collective punishment) via the wage premium required to keep an agent with a "reputation" for cheating honest. Since an agent subject to multilateral punishment was not expected to be hired by any other merchant, his loss from cheating if re-hired was less than that of an "honest" agent. Given a choice, merchants would not wish to hire a cheater since it was necessary to pay him more than an honest agent to induce cooperation. Thus, in Greif's analysis the multilateral punishment strategy is made self-enforcing by the wage differential between honest agents and cheaters.

Two issues arise in Greif's formulation of the Maghribi's collective punishment strategy which deserve reconsideration. The first is that the specified multilateral punishment strategies are only an equilibrium if there are literally no costs to merchants of switching agents, or if every agent's actions are observed by every merchant. In the absence of one or another of these assumptions, merchants will never wish to fire an agent who has cheated, so agents will always cheat, and the equilibrium unravels.[3] But Greif himself tells us that switching agents was costly for the Maghribi merchants, and we shall argue that the assumption of *multilateral* (as opposed to *bilateral*) perfect information is not supported by the historical evidence. Indeed, the historical evidence makes it clear that although Maghribi merchants may

[2]See also Greif, Milgrom and Weingast (1994) who use a multilateral reputation mechanism to support efficient trade between medieval cities and merchant guilds.

[3]This is true so long as we restrict attention to the "simple" punishment strategies used by Greif (1993), which prohibit "second" and "higher-order" punishments, on the grounds of historical plausibility. See the discussion below.

have been able to monitor the actions of their own agents with considerable accuracy (justifying the assumption of bilateral perfect information), they did not directly observe the actions of other merchants' agents. Hence the equilibrium strategies specified in Greif (1993) would not appear to be sustainable under more realistic historical assumptions.

The solution to this problem turns out to be contained in Greif's own reports of the way the Maghribi traders actually dealt with agents whom they believed had cheated them. The Maghribis punished transgressions by ostracizing (i.e. firing and not re-employing) an agent who had cheated until compensation was paid to the victim. Once compensation had been paid, normal commercial relations with the agent were resumed. We show that with compensation of this type there is a multilateral punishment strategy equilibrium similar to the equilibrium specified by Greif, but supported by different equilibrium strategies, and which allows for the same level of mutually advantageous trade to occur. In our equilibrium, if an agent cheats he is never fired, but pays the merchant compensation which (weakly) exceeds the one period gain from cheating, and is less than the net payoff from remaining unemployed forever. Agents will always choose to pay such compensation in equilibrium, and this prevents cheating in Greif's efficiency wage model. This formulation of the Maghribi's "punishment strategies" thus incorporates a principal component of the Maghribi's actual historical practice into the model and explains why it may have been necessary to sustain cooperation.

In addition, our analysis also shows why the Maghribi practice of allowing any trader to cheat a merchant who had himself been accused of cheating, may have been needed to discourage merchants from making false accusations of cheating. Given a likely prospect of receiving compensation, merchants will strictly prefer to report that their agent has cheated, whether he has or not. This issue does not arise in Greif's (1993) formulation of the equilibrium strategies, since merchants had no incentive to make false reports in his analysis.

Despite the obvious merit of analyzing the actual "institution" used by the Maghribis to support cooperation, and under more plausible historical assumptions, our model nevertheless predicts the same level of trade in equilibrium as Greif's (and punishments are never used in either model). Hence the predictions of the two models are observationally equivalent under either multilateral or bilateral perfect information. An important advantage of the use of compensation to sustain cooperation, however, is that it is a more efficient institution in the presence of uncertainty, or an inability to perfectly monitor agents' actions. We therefore extend Greif's model by allowing for a small amount of uncertainty over whether an agent has cheated or not in any period (i.e. bilateral imperfect information), and for the equilibrium level of trade to be endogenously determined. The predictions of the two models then no longer coincide. Under the collective punishment strategy used by Greif (1993), a lower value of trade is chosen by merchants in every period than in the equilibrium supported by compensation payments. Further, under Greif's specification of his model, cooperative trade collapses once a sufficient number of agents acquire a reputation for cheating. This problem does not beset the punishment strategy requiring incentive-compatible compensation payments to be made.

The second issue with Greif's analysis is that his efficiency wage model does not correspond very closely to the actual structure of Maghribi trading relationships. According to Greif's (1993) historical evidence (see also Greif, 1989; and Greif, 2006, Chapters 3 and 9), the Maghribi traders were a "closed coalition" who did not hire "outsiders" as agents, and who typically acted as agents and partners for each other in a network of intertwined, long-run relationships.[4] This structure of trade through bilateral and multilateral partnerships and "formal friendships" is not that specified in Greif's efficiency wage model.[5]

When the model is adapted to reflect the specific structure of Maghribi trading relationships, different and interesting conclusions emerge. For example, once traders act as both merchants and agents, we can easily predict the Maghribi's common practice of trading through "formal friendships" in which they provided each other with agency services without pecuniary compensation, in contrast to the efficiency wage model. And under bilateral imperfect information, compensation strategies allow for (weakly) lower wages and higher levels of welfare to be sustained in equilibrium, since traders act-

[4] The predominant forms of trading relationship were partnerships and "formal friendships." See Goitein (1967), Chapters III.B.1-III.B.4, and Greif (2006), Chapter 9.

[5] Nor does it correspond to his model of bilateral trade (Greif, 1993, Section 4). His model would appear to correspond more closely to a situation in which a group of merchants hires agents from a large pool of outsiders.

ing as agents no longer face the risk of being ostracized when falsely accused of cheating. We are also able to dispense with some other assumptions required in Greif's analysis which are not strongly supported by the historical evidence.

The equilibrium strategies posited in this paper to sustain cooperation between widely-dispersed medieval traders would seem to more accurately reflect, and explain, actual Maghribi practices. They also show how the Maghribi traders avoided the inefficiencies involved in permanently ostracizing valuable trading partners, while still providing incentives for cooperation. This is a desirable property in a world of imperfect information and imperfect monitoring in which mistakes (i.e. false accusations of cheating) were likely to occur.

Section 2 presents Greif's efficiency wage model and describes the new equilibrium strategies. Section 3 extends the model to allow for bilateral imperfect information and endogenously determined levels of trade. Section 4 presents some simple results on modelling formal friendships, with and without bilateral imperfect information. Section 5 considers related literature and concludes.

2 The Efficiency Wage Model of Maghribi Trading Relationships

Greif (1993) considers a complete information game with M merchants and A agents, each of whom lives an infinite number of periods. There are assumed to be more agents than merchants, $A > M$. Agents and merchants have a common time discount factor δ, and an unemployed agent receives a per period reservation utility of $\overline{w} \geq 0$. In each period, an agent can be employed by only one merchant and a merchant can employ only one agent. A merchant who does not employ an agent receives a payoff of $\kappa > 0$, and the gross gain from cooperation (i.e. employment) is γ.

A merchant who hires an agent decides what wage, $W > 0$, to offer the agent. Since an employed agent holds the merchant's capital, an agent is ensured of receiving his wage. An agent who is offered employment decides whether to be honest or to cheat in any period. If the agent is honest, the merchant's one-period payoff is $\gamma - W$, and the agent's payoff is W. If the agent cheats, his payoff is $\alpha > 0$ and the merchant's payoff is 0. Greif (1993) assumes that $\gamma > \kappa + \overline{w}$, $\gamma > \alpha > \overline{w}$, and $\kappa > \gamma - \alpha$.[6]

After the allocation of the payoffs, each merchant decides whether to terminate his relations with his agent and search for a new agent. There is a probability $\tau > 0$, however, that a merchant is forced to fire his agent in any period. Matching of unemployed agents with searching merchants is random, but a merchant can make his hiring or retention decisions contingent upon the actions previously taken by an agent.

Finally, Greif (1993) assumes "perfect information" in his model. We will find it helpful in what follows to distinguish between two different concepts of perfect information. By *bilateral perfect information* we shall mean that each merchant can perfectly monitor the actions of any agent he employs, but not those of agents employed by other merchants. By *multilateral perfect information* we shall mean that every merchant can perfectly monitor the actions of every agent, whether employed by him or not. As we shall see, the equilibrium strategies required to sustain cooperation will depend critically on which of these types of perfect information is assumed.

Following Greif (1993), we will consider only historically plausible *simple* punishment strategies in constructing an equilibrium. Simple punishment strategies do not involve cheaters "collaborating" in their own punishments, by punishing merchants who fail to punish cheating agents, and so on.[7] Given this restriction, Greif specifies multilateral punishment strategies in which in each period each merchant offers an agent a wage W^*, retains the agent if he was honest unless forced separation occurs, fires the agent if he has cheated, never hires an agent who has ever cheated any merchant, and randomly chooses an agent from amongst the unemployed agents who have never cheated if forced separation occurs. An "honest" agent's strategy (i.e. an

[6] These conditions imply respectively that cooperation is efficient; cheating entails an efficiency loss and agents prefer cheating to receiving their reservation utility; and merchants prefer not hire an agent over paying a wage as high as the amount that the agent can cheat them by.

[7] It has now become commonplace amongst sociobiologists to argue that we should not expect to see 'second' and 'higher-order' punishments being used in real human groups (see McElreath and Boyd 2005). Gintis (2004) claims that examples of the use of such strategies in small-scale, or 'hunter-gatherer', societies are nonexistent.

agent who has never cheated in the past) is to be honest if offered W^* and to cheat if offered less than W^*. A "cheater's" strategy is cheat unless offered a wage $W_c^* > W^*$. Greif (1993) demonstrates that these strategies can support a (subgame perfect) equilibrium in which merchants will never wish to hire an agent who has a "reputation" for cheating.[8]

To see this, let h denote the probability that an unemployed "honest" agent (an agent who has never cheated in the past) will be rehired in any period, V_h the lifetime expected utility of an employed honest agent, and V_h^u the lifetime expected utility of an unemployed honest agent. Similarly, V_c and V_c^u denote the expected lifetime utilities of an employed and unemployed "cheater" respectively (i.e. of an agent who has *ever* cheated in the past). Proposition 1 in Greif (1993) solves for the lowest wage W^* for which an agent's best response is to be honest in any period.[9]

Proposition 1 *Assume $\delta, \tau, h \in (0,1)$. The lowest wage for which an 'honest' agent's best response is to be honest is $W^* = w(\delta, h, \tau, \overline{w}, \alpha) > \overline{w}$, where $w(\cdot)$ is monotonically decreasing in δ and h and monotonically increasing in τ, $\overline{w}$, and α.*

Proof. For a given wage W, agents' lifetime expected utilities can be written,

$$\begin{aligned} V_i &= W + (1-\tau)\delta V_i + \tau\delta V_i^u, \;\; i = h, c \\ V_h^u &= hV_h + (1-h)(\overline{w} + \delta V_h^u) \\ V_c^u &= \overline{w} + \delta V_c^u. \end{aligned}$$

The payoff from cheating once and then becoming an unemployed "cheater" is given by $\alpha + \delta V_c^u$.[10] Setting $V_h(W^*) = \alpha + \delta V_c^u$ and solving for W^* yields,

$$W^* = [T - \delta\tau H]\left[\alpha + \frac{\delta\overline{w}}{1-\delta}\right] - \tau\delta P\overline{w} \tag{1}$$

[8] Greif (1993) restricts attention to equilibria supported by symmetric and stationary strategies. Other types of equilibria are possible when these restrictions are relaxed.

[9] We have simplified Greif's (1993) formulation as we are not concerned with the analysis of bilateral punishment strategies exposited in his Proposition 3. We have otherwise followed Greif's specification as closely as possible to keep comparisons with his analysis simple.

[10] Note that this assumes that merchants will fire a cheater, an issue taken up below.

where,

$$\begin{aligned} T &= 1 - \delta(1 - \tau) \\ H &= \frac{h}{1 - \delta(1 - h)} \\ P &= \frac{1 - h}{1 - \delta(1 - h)} \end{aligned} \tag{2}$$

The properties of w can be derived directly from this expression. ∎

W^* is the minimum wage required to induce cooperation from agents who have never cheated in equilibrium. Setting $h = 0$ in (1) defines W_c^*, the minimum wage required to induce honesty in an agent who has a reputation for cheating. Since $W_c^* > W^*$, the wage required to induce honesty from an agent who has cheated in the past is higher than that required to induce cooperation from honest agents. Hence, so long as the number of honest unemployed agents (weakly) exceeds the number of merchants searching for an agent in any period, merchants will always prefer to hire an honest agent.

Note that there will only be trade if $W^* \leq \gamma - \kappa$, requiring an additional assumption on the parameters. Assuming that this is satisfied, it is easy to show that offering any higher stationary wage $W^{**} > W^*$ can never be a (subgame perfect) equilibrium given the restrictions on the strategies.[11] However, autarky (or no trade) can also always be an equilibrium.[12,13]

[11] I.e. that they are 'symmetric' and 'simple'. To show this we need to assume that cheating by an agent when offered a wage lower than W^{**} is sufficient to invoke the multilateral punishment strategy, which appears to have been intended by Greif (1993). Otherwise, there will be a continuum of subgame perfect equilibria supported by wage offers in the range $W^* \leq W^{**} \leq W_c^*$.

[12] An autarkic equilibrium can be constructed by specifying the following strategies: merchants never hire agents and fire any agent they have hired at the end of each period, whether the agent has cheated or not. Agents always cheat if offered a wage less than α. Clearly these strategies form an equilibrium, and permanent reversion to them in response to an agent cheating could have been used to sustain the same equilibrium outcome as that obtained in Proposition 1.

[13] Strictly speaking, to have demonstrated the existence of a subgame perfect equilibrium we need the specified strategies to be an equilibrium after every possible history, which they are not (see Fudenberg and Tirole, 1991, pp. 108-110). The relevant histories are those which result in there being fewer remaining honest agents than there are merchants, so the multilateral punishment strategy is no longer viable (i.e. self-enforcing). We can simply specify a permanent reversion to the autarkic strategies after every such history, however.

If the probability of forced separation is assumed to be zero in the above expressions ($\tau = 0$), then we would have $W_c^* = W^*$, so merchants would be indifferent between hiring an honest agent or a former cheater. This is because under *simple* punishment strategies, an agent's strategy does not call on him to cheat any merchant who hires him simply because he has cheated in the past (i.e. agents do not punish merchants for not following the multilateral punishment strategy).[14] As Greif (1993) observes, the equilibrium would then rest on a "knife-edge" in which merchants only carried out the multilateral punishment strategy because of indifference. The role of the exogenous probability of forced separation is to break this indifference by making the expected lifetime utility of an employed honest agent exceed that of an employed cheater, even if the "cheater" intends to play honest in the future, resulting in $W_c^* > W^*$. As Greif (2006), pp. 76-77, puts it,

> "*The possibility of forced separation links the optimal wage a particular merchant has to pay his agent and the agent's expected future relations with other merchants. This link increases the optimal cheater's wage above an honest agent's wage. Hence merchants find it optimal to follow the multilateral punishment, despite the fact that the agent's strategy does not call for cheating any merchant who violated the collective punishment, and despite the fact that cheating in the past does not indicate that the agent is a "lemon."*"

2.1 The Problem and a New Approach

In the equilibrium described by Proposition 1, merchants strictly prefer not to *hire* an agent with a reputation for cheating because of the wage differential $W_c^* - W^*$. But why should a merchant should prefer to *fire* an agent who has cheated him and search for a new agent? If we allow for only *bilateral perfect information* in the model, merchants will be indifferent between retaining or firing either a cheater or an honest agent. This is because nothing is learned about an agent from observing off-the-equilibrium-path behavior

[14] Hence merchants would also be indifferent between firing an agent who cheats them and retaining him, since all agents' continuation strategies call on them to play honest if offered the wage $W_c^* = W^*$.

(i.e. cheating),[15] and under Greif's specification of the equilibrium strategies, agents are not required to punish merchants who violate the collective punishment strategy. Hence a merchant who fires an agent who has cheated and hires a new agent - assuming that the new agent will play the hypothesized equilibrium strategy - can equally well make the same assumption about the agent he has already hired.[16] So for any small cost of severing the agency relationship and searching for a new agent, merchants will strictly prefer to retain their current agent, whether he has cheated them or not. Given this, agents who cheat will not be fired, so all agents will cheat and no agent will ever be hired. Merchant-agent trade relations cannot be sustained.[17]

One could argue that since it is implicitly assumed in the model that switching agents does not impose any cost, a merchant might as well fire a cheater and hire a new agent. However, severing relations with a formerly trusted agent was costly to the Maghribis, as Greif (1993)(2006) makes clear in explicitly rejecting this approach.[18] Since for *any* cost of switching agents (no matter how small), merchants will *strictly* prefer to retain their current agent, the specified strategies will not be an equilibrium if only bilateral perfect information is assumed.

Can this problem be resolved in a way which restores the essential prop-

[15] What players should deduce from observing a zero-probability (off-the-equilibrium-path) event is a much-discussed issue. As Dixit (2003) points out in a similar context, any inference is consistent with observing such an event. Sustaining an equilibrium by assigning arbitrary beliefs to traders at such junctures would clearly violate the historical spirit of the exercise, however.

[16] That is, if an agent cheats in period t, in the subgame beginning at $t+1$, if the agent hasn't been fired and declared a cheater, his optimal strategy is not to cheat if he expects to return to the equilibrium path of play.

[17] An obvious approach would be to apply the idea of "renegotiation-proofness" (Fudenberg and Tirole, 1991, Ch. 5; Farrell and Maskin, 1989; Farrell 2000). For any small cost of severing the agency relationship, the merchant and agent would want to renegotiate the equilibrium strategies if the agent has strayed from the equilibrium path and cheated (see Proposition 3 below). Greif, Milgrom and Weingast (1994), for instance, appeal to the concept of renegotiation-proofness to explain why the ruler of a medieval city could not have been relied upon to punish violators of a merchant embargo by cheating them, when mutually profitable trade was possible on terms which the ruler would credibly respect.

[18] See Greif (2006), p. 76 (also Greif, 1993, p. 534): "*When switching agents does not impose any cost—as assumed here—merchants may as well punish a cheater, hence the multilateral punishment strategy is a subgame perfect equilibrium. Having the credibility of multilateral punishment rest on a knife-edge result, however, is unsatisfactory. Clearly, Maymun be Khalpha considered that punishing the Sicilian agent was costly.*"

erties of the multilateral punishment strategy equilibrium? One way of doing so is to follow Greif (2006) in assuming that cheating by *any* agent is *publicly observed*, so he will be identified as a cheater even if the merchant he is engaged by does not wish to report the transgression. Then, assuming that all other merchants will follow the hypothesized equilibrium strategy of not hiring an agent who has cheated, the merchant in question will also wish to follow the equilibrium strategy and fire the agent.[19] That is, in the presence of small switching costs, the assumption of *multilateral* perfect information is necessary to support cooperation in equilibrium.

From the evidence provided by Greif (1993)(2006) and Goitein (1973), it seems doubtful that it could be argued that this is a realistic approach. Some third-party monitoring of agents appears to have occurred, but it is not clear that an agent could be identified as a cheater if the merchant in question made no such accusation.[20] Direct evidence for this comes from the letters of the Maghribi traders themselves. These show that the Maghribis sometimes kept their affairs secret from other traders, and felt the need to inform their trading partners of the transgressions or good behavior of the agents they had dealings with. For example, in Letter 8 of Goitein (1973), a Maghribi trader acting as an agent informed his correspondent that the consignment he was in charge of was the property of a certain other trader, "*...but no one knows this except myself.*"[21] He also added that this trader had acted honorably when acting as an agent for him, so "*... no heedlessness is permissible with regard to his rights.*" In another letter, a trader involved in a lawsuit before the rabbinical court of Fustat expressed his wish that his opponent would have returned "*to the right way...so that I would not be forced to make known his doings to the communities of Israel in east and*

[19] This assumes that the switching costs are small enough relative to the wage differential, $W_c^* - W^*$. We shall always assume that switching costs are "small" in the relevant sense in what follows.

[20] For example, Greif (2006), pp. 67-68, tells us that agents' remuneration typically included both a wage and a share of the trading profits. It seems unlikely that the balance between these variables in any particular merchant-agent relationship was publicly observed, so no third party could necessarily verify that an agent had cheated in the absence of an accusation from the merchant involved.

[21] The agent was evidently confiding in his correspondent to avoid any risk of being accused of having absconded with the merchant's goods, should anything untoward have occurred to the merchant in question on a sea voyage.

west."[22]

Thus although merchants may have been able to monitor the actions of their own agents with considerable accuracy - justifying the assumption of *bilateral* perfect information as a reasonable approximation - it seems clear that they did not directly observe the actions of other merchants' agents, but needed to be informed of them. Hence the assumption of publicly observable actions seems untenable as an approach to sustaining multilateral punishment strategies as an equilibrium.

Another solution which does not require the assumption of multilateral perfect information *is* mentioned in the historical evidence, however. An agent who was identified as a cheater could have his record wiped clean by paying compensation to the merchant he had cheated, i.e. "*ostracized agents were considered cheaters until they compensated the injured party*" (Greif, 1993). This compensation scheme plays no role in Greif's own model, but it can solve the problem with the equilibrium strategies we have identified above. To see this, note that a merchant's lifetime expected profits (denoted V^M) from engaging an agent are

$$V^M = \frac{(\gamma - W^*)}{(1-\delta)}, \tag{3}$$

if he is not cheated, and

$$V^M = \frac{\delta(\gamma - W^*)}{(1-\delta)} - \varsigma, \tag{4}$$

if he is cheated once and then expects to return to the equilibrium path of play with a different agent, where $\varsigma > 0$ is his switching cost.[23] If he is cheated once and then expects to return to the equilibrium path of play *with the same agent*, however, he saves the switching cost ς, and so strictly prefers retaining the agent who cheated him over incurring the cost of finding a new agent. The equilibrium in multilateral punishment strategies cannot be sustained.

[22] Goitein (1973), Letter 17.

[23] Throughout what follows we will ignore the fact that merchants will be forced to switch agents by exogenous events, which could be dealt with by subtracting the discounted expected lifetime switching costs thereby incurred from these and the following expressions.

Suppose instead that a merchant who fires a cheating agent can expect to receive a compensation payment with a present discounted value of C. His profits from switching agents are then,

$$V^M = \frac{\delta(\gamma - W^*)}{(1-\delta)} - \varsigma + C. \tag{5}$$

So long as $C > \varsigma$, the merchant strictly prefers to fire the agent as required to sustain the equilibrium strategies. Can such a compensation system sustain both the agents' and merchants' incentives so that agents are hired in equilibrium?

First note that for any level of compensation, a merchant prefers to retain an agent who cheats and then *immediately* pays compensation over firing the agent. So we need to find a wage rate and levels of compensation which induce agents to act honestly, and which induce agents who have cheated to prefer paying compensation immediately over becoming unemployed forever (or paying compensation later). Proposition 2 establishes the required wage and compensation levels.

Proposition 2 *There exists a minimum wage rate $\widehat{W}$ and maximum compensation levels, $\widehat{C}_0, \widehat{C}_1$, such that:*

(i) *agents (weakly) prefer playing honest over cheating and paying the compensation $\widehat{C}_0$ immediately;*

(ii) *agents (weakly) prefer paying the compensation $\widehat{C}_0$ immediately over becoming unemployed forever;*

(iii) *an agent who has cheated in period t will (weakly) prefer to pay the compensation $\widehat{C}_0$ immediately over waiting one period and paying compensation $\widehat{C}_1$ in period $t+1$;*

(iv) *an agent who has cheated in period t and not paid the compensation $\widehat{C}_0$ will (weakly) prefer to pay the compensation $\widehat{C}_1$ immediately over staying unemployed forever; and*

(v) *an agent who has cheated in period t and not paid the compensation $\widehat{C}_0$ will (weakly) prefer to pay the compensation $\widehat{C}_1$ immediately over waiting one more period before paying compensation.*

In addition, $\widehat{W_c} > \widehat{W}$, so the wage required to induce cooperation from agents who have cheated in the past and not paid compensation exceeds the *wage required to induce cooperation from 'honest' agents. Further, $\widehat{W} = W^*$ as defined in Proposition 1, so the same level of trade is sustained in equilibrium.*

Proof. For an agent to prefer being honest over cheating once and paying compensation immediately, we must have

$$V_h \geq \alpha - \widehat{C}_0 + (1-\tau)\delta V_h + \tau\delta V_h^u, \tag{6}$$

or $\widehat{C}_0 \geq \alpha - \widehat{W}$. That is, if the agent cheats to obtain α, if he immediately pays compensation he stays on the equilibrium path and receives $(1-\tau)\delta V_h + \tau\delta V_h^u$ from that point onward. In order for an agent to prefer paying compensation immediately over becoming unemployed forever we must have,

$$-\widehat{C}_0 + (1-\tau)\delta V_h + \tau\delta V_h^u \geq \delta V_c^u, \tag{7}$$

or, $\widehat{C}_0 \leq V_h - \widehat{W} - \delta V_c^u$.

We must show three further things to establish the result. First, that an agent who has cheated in period t will prefer to pay compensation immediately over waiting one period and paying compensation in period $t+1$; second, that an agent who has cheated in period t and *not* paid compensation will prefer to pay compensation in period $t+n$, $n = 1, 2, \ldots$, over staying unemployed forever; and third, that an agent who has cheated and *not* paid compensation at any point in the past will always prefer to pay immediately over waiting one more period before paying compensation. The first requires,

$$-\widehat{C}_0 + (1-\tau)\delta V_h + \tau\delta V_h^u \geq -\delta\widehat{C}_1 + \delta V_h^u \tag{8}$$

where the compensation payment required from period $t+1$ onwards is $\widehat{C}_1$.[24] This implies that,

$$\widehat{C}_1 \geq \frac{\widehat{C}_0}{\delta} - (1-\tau)(V_h - V_h^u). \tag{9}$$

The second requires that,

$$-\widehat{C}_1 + V_h^u \geq V_c^u, \tag{10}$$

[24] Note that an agent who pays compensation in period $t+n, n = 1, 2, \ldots$ joins the honest agents' "unemployment queue" and obtains the expected payoff V_h^u from that point forward.

or $\widehat{C}_1 \leq V_h^u - V_c^u$. Third, we must have,

$$-\widehat{C}_1 + V_h^u \geq \overline{w} - \delta\widehat{C}_1 + \delta V_h^u, \tag{11}$$

or $\widehat{C}_1 \leq V_h^u - V_c^u$.

Setting $\widehat{C}_0 = V_h - \widehat{W} - \delta V_c^u$ (i.e. at its maximum) and substituting, we may rewrite (9) as,

$$\widehat{C}_1 \geq V_h^u - V_c^u. \tag{12}$$

So we must have $\widehat{C}_1 = V_h^u - V_c^u$. The lowest wage $\widehat{W}$ consistent with these conditions is then given by $\widehat{W} = \alpha - \widehat{C}_0$. At this wage rate

$$\alpha - \widehat{W} = \widehat{C}_0 = V_h - \widehat{W} - \delta V_c^u, \tag{13}$$

hence $\alpha = V_h - \delta V_c^u$, or $V_h(\widehat{W}) = \alpha + \delta V_c^u$. From Proposition 1 it follows immediately that $\widehat{W} = W^*$ and $\widehat{C}_1 < \alpha$.

It remains to show that $\widehat{W} < \widehat{W}_c$. This can be easily established by following a similar line of reasoning to that employed above. If a cheating agent who hasn't paid compensation is rehired, his expected lifetime utility is

$$V_c = \widehat{W}_c + (1-\tau)\delta V_c + \tau\delta(V_h^u - \widehat{C}_1), \tag{14}$$

since if he loses his employment due to exogenous events the agent's optimal strategy is to pay the compensation $\widehat{C}_1$ in the following period. For the agent to prefer being honest over cheating and paying compensation $\widetilde{C}_0$ immediately requires,

$$V_c \geq \alpha - \widetilde{C}_0 + (1-\tau)\delta V_c + \tau\delta(V_h^u - \widehat{C}_1), \tag{15}$$

or $\widetilde{C}_0 \geq \alpha - \widehat{W}_c$. For the agent to prefer paying compensation immediately over becoming unemployed forever requires,

$$-\widetilde{C}_0 + (1-\tau)\delta V_c + \tau\delta(V_h^u - \widehat{C}_1) \geq \delta V_c^u, \tag{16}$$

or, $\widetilde{C}_0 \leq V_c - \widehat{W}_c - \delta V_c^u$. Since the agent will never be willing to pay $2\widehat{C}_1$ if he is fired for cheating a second time, we need consider no further conditions. Thus $(\widehat{W}_c,\widetilde{C}_0)$ must satisfy,

$$\alpha - \widehat{W}_c \leq \widetilde{C}_0 \leq V_c - \widehat{W}_c - \delta V_c^u. \tag{17}$$

Finding the lowest wage and highest level of compensation which induce cooperation requires $V_c(\widehat{W}_c) = \alpha + \delta V_c^u$. It follows immediately that $\widehat{W}_c > \widehat{W}$ and $\widetilde{C}_0 < \widehat{C}_0$. Hence merchants always prefer to hire an agent who has never cheated (or an agent who has cheated and paid compensation), over hiring an agent who has cheated and not paid compensation. ■

Under the wage-compensation scheme specified in Proposition 2, a merchant receives at most $\alpha - \widehat{W}$ from an agent who has cheated, so merchants are not fully compensated. Since merchants still strictly prefer to receive $\widehat{C}_0$ from their current agent over firing them and searching for a new agent, for any $\varsigma > 0$ merchants will retain cheating agents who pay them the required compensation.

Traders' strategies in the equilibrium with compensation are then: (i) honest agents are offered $\widehat{W}$ in every period; (ii) an agent who cheats in any period is fired unless he immediately pays compensation $\widehat{C}_0$ to the original merchant; (iii) an unemployed cheater is never employed by any merchant until he pays compensation $\widehat{C}_1$ to the original merchant; and (iv) agents are honest if offered $\widehat{W}$, pay compensation $\widehat{C}_0$ immediately if they cheat, and merchants only hire honest agents.

In this equilibrium, a merchant will never hire an agent who has cheated and not paid compensation for the same reason that merchants don't hire cheating agents in Greif's model, i.e. because $\widehat{W}_c > \widehat{W}$. The compensation payments, however, have resolved the issue of why a merchant should *fire* a cheating agent who hasn't paid compensation. He will do so because if the agent has cheated and hasn't paid compensation in period t, the agent's best response to being fired and unemployed in period $t+1$ is to pay compensation in period $t+1$.

The remaining issue with the equilibrium strategies is that merchants now *strictly* prefer to declare their current agent a cheater in order to receive the compensation $\widehat{C}_0$, whether he has cheated or not, over retaining an honest agent.[25] So long as disputes over whether or not an agent had cheated could be adjudicated with reasonable accuracy, however, false accusations of cheating were unlikely to occur. Greif (2006) argues that this was the case, and also that making false declarations would be very costly to merchants,

[25] In Greif (1993) merchants have no positive incentive to make false declarations of cheating.

vis[26]

> "*False accusations of cheating were curtailed by the extensive use of witnesses to testify to one's honesty. ... Eleventh century Maghribi agents generally conducted important business in the presence of other coalition members. In their reports they included the names of witnesses the merchant knew, thus enabling the merchant to verify the agent's report.*"

And ,

> "*an insider merchant puts his own reputation on the line in accusing an agent.*"

To model this we assume, as indicated by the historical record, that a merchant who made a dishonest report would be discovered with some probability $\rho \in (0, 1)$, and would be unable to hire agents in the future, because they would cheat him and not pay compensation. As Greif (1993) notes, traders who had been accused of cheating could in turn be cheated by other Maghribi traders without their being subject to community retaliation.[27] The historical documents do not specify the duration of such a punishment strategy, so we will assume that it lasts for a single period only. A merchant who makes a false accusation of cheating would then have an expected payoff $V_c^M(\rho)$ given by,

$$V_c^M(\rho) = (1-\rho)\left[(\gamma - \widehat{W}) + \widehat{C}_0 + \frac{\delta(\gamma - \widehat{W})}{(1-\delta)}\right] + \rho\left[(\gamma - \widehat{W}) + \frac{\delta^2(\gamma - \widehat{W})}{(1-\delta)}\right], \quad (18)$$

[26] See Greif (2006), p. 64 and p. 82.

[27] Greif (1993), p. 535, tells us that "an agent who cheated a cheater" was not subject to multilateral punishment (see also Goitein, 1973, p.104; and Greif, 1989). Similar forms of punishment strategy are found among the Orma herders of East Africa (Ensminger, 1992, Chapter 4; Dixit, 2004, p. 62), and the Ju/'hoansi bushmen (Wiessner, 2005). 'Cheat the cheater' strategies of a different type to those employed by the Maghribis, Orma or Ju/'hoansi are used by Kletzer and Wright (2000) to support renegotiation-proof equilibria in a repeated borrower-lender game. Their strategies require a 'coalition' of a borrower and a lender to form to upset the strategy of a lender who has failed to cooperate in the borrower's punishment.

since a merchant's payoff from being cheated once is just 0. Ensuring that cheating by making a false declaration is unprofitable requires that $V^M \geq V_c^M(\rho)$, or

$$(1-\rho)\widehat{C}_0 \leq \rho\delta(\gamma - \widehat{W}) \tag{19}$$

Hence for a probability of detection in the range $\rho \in [\underline{\rho}, 1)$, where $\underline{\rho}$ is defined by $V^M = V_c^M(\underline{\rho})$, making a false declaration will be unprofitable.[28]

Proposition 3 *Assume* $\delta, \tau \in (0,1)$, $h = \frac{\tau M}{A-(1-\tau)M}$ *and the wage rate and compensation levels* ($\widehat{W}$, $\widehat{C}_0, \widehat{C}_1$) *as specified in Proposition 2. Further assume that* $\rho \geq \frac{\widehat{C}_0}{\delta(\gamma-\widehat{W})+\widehat{C}_0} = \underline{\rho}$. *Then the strategies specified above form a "weakly renegotiation-proof" equilibrium.*

Proof. The result follows directly from the natural generalization of the Farrell and Maskin (1989) definition of weakly renegotiation-proof strategies,[29] and the construction of the strategies specified above. ■

This structure of the equilibrium strategies appears to more accurately reflect actual Maghribi practice and the informational constraints they operated under. Indeed, an equilibrium supported by compensation strategies has a number of desirable properties. First, it utilizes the Maghribi's actual 'punishment strategies' to resolve the issue of why traders should fire cheating agents, and also to explain how merchants were discouraged from making false declarations of cheating. In doing so it dispenses with the need to assume either that the actions of all agents were observable by all merchants, including those they did not employ, or that agent switching costs were literally zero.

Second, it explains why merchants' incentives to make false declarations of cheating (in order to obtain compensation) needed to be as closely monitored as agents' incentives to cheat merchants. The purpose of witnesses was as much to protect agents from false accusations, as to protect merchants from

[28] Note that agents will strictly prefer to cheat a merchant who has cheated, under the specified punishment strategy. A sufficient condition for a merchant to prefer submitting to the punishment, as opposed to operating outside the coalition forever is, $[1-\delta(1-\delta)](\gamma - \widehat{W}) \geq \delta\kappa$. This is true for all $\delta \in (0,1)$ given our assumption that $\gamma - \widehat{W} - \kappa > 0$, i.e. that mutually profitable trade can be supported in equilibrium.

[29] See Farrell's (2000) definition of "quasi symmetric weak renegotiation-proofness"; also Aramendia, Larrea and Ruiz (2005), Definition 2.

being embezzled. A high enough probability of detection of false accusations (ρ) was essential to sustaining merchant-agent cooperation.

Third, it is a more efficient institution in a world of imperfect information and imperfect monitoring in which some "mistakes" or "transgressions" were likely to occur. It saves both on the costs of firing agents who have cheated, and also on the cost of permanently ostracizing valuable trading partners from the coalition. Since the model with perfect and complete information is clearly intended only as an approximation to the 'noisier' world in which the Maghribis actually operated, this is a desirable property.[30]

The interesting historical questions are then, what level of compensation payment was required by the Maghribi traders? How were disputes over whether or not an agent had cheated resolved? Did merchants retain (or immediately rehire) agents who paid them compensation?

Again, evidence in the Maghribi's letters provides some support for our approach. The merchant writing in Letter 18 cited above makes it clear that if his opponent in the lawsuit had "*reconsidered the affair*" and paid him the compensation for losses he thought was owed, he would have re-established normal commercial relations with him, and not have "*made known his doings.*" Another trader writing in Letter 51 explains that a similar dispute he was involved in was settled, and he had released his agent from his debt for a payment of 100 dinars. He invited his correspondent to "*please take note of this*," implying that re-establishing normal commercial relations with the agent was now considered permissible. And Greif (1993), p. 530, tells us that the Maghribi traders ostracized an agent in Jerusalem who had embezzled the money of one of them and, "*only after a compromise was reached and he had compensated the offended merchant, were commercial relations with him resumed.*"

[30] Two different models in which bilateral imperfect information leads to such 'mistakes' occurring with positive probability are considered in Sections 3 and 4 below.

3 A Model with Trading Uncertainty and Endogenous Levels of Trade

The two models of Maghribi trading relationships considered in Section 2 both predict that cooperative trade will be sustained at a wage rate of $W^* = \widehat{W}$, and that no punishments or compensation payments will ever occur. In this sense the predictions of the models are observationally equivalent, so one might ask what the point was of introducing compensation payments in the first place. One good answer is that it is important to model historical 'institutions' as they actually were, even if other models or different 'institutions' can yield the same or similar results. The purpose of the historical enquiry is to understand how the obstacles to trade in the early Mediterranean period were overcome in the absence of reliable or enforceable legal contracts. An imperfect ability to monitor the behavior of other merchants' agents, and the costs of switching agents, were both obstacles to incentive-compatible trade faced by the Maghribi traders, so any realistic model should take them into account.[31]

Nevertheless, an important advantage of the actual Maghribi practice of requiring agents who had 'cheated' to pay compensation, was that it was a more efficient institution in the face of uncertainty, or an inability to perfectly monitor *any* agents' actions.[32] So it will be useful to provide an example of a model in which merchants and their agents face significant uncertainty, and in which the predictions of the two models no longer coincide.

Trade in the early Mediterranean period was a risky activity, and subject to possible calamity. Ships and their cargoes could be lost at sea, or rerouted by storms, and land voyages were equally fraught with dangers.[33] Hence when

[31] Indeed, as we have argued in this paper, the Maghribis probably could not have sustained trade solely on the basis of the collective punishment strategy considered by Greif (1993), since any such strategy would have failed to provide adequate incentives to fire cheating agents.

[32] And Greif (2006), p.65, tells us that, "*the ability to monitor was imperfect; a merchant could mistakenly conclude that an agent was dishonest.*"

[33] The letters in Goitein (1973) provide many interesting and vivid examples of this. Goitein (1973), pp. 7-8, notes that, "*a man shipping his goods overseas normally had to wait months before he could know what happened to them,*" and mentions 'whims of nature' such as storms at sea, famines and epidemics, as well as ruthless governments and "*the constant menaces of piracy and war*", as all impinging upon the reliability of trade (see also Goitein, 1973, pp. 10-11). Letter 9 of Goitein, for example, concerns a shipment of

an agent was entrusted with a merchant's goods, there was always some risk that he would be unable to make good on his employment contract for reasons which were beyond his control. Although in many cases merchants would have been able to verify reports of losses from their agents due to 'whims of nature', there were also occasions when such verification was not possible.[34] In such events, merchants would have needed to decide whether to punish their agent for cheating, or to simply let bygones be bygones. Punishing the agent may have meant perpetrating an injustice against the innocent, but letting bygones be bygones would have provided strong incentives for the false reporting of losses by agents.[35]

To encompass these possibilities in the simplest possible way, we will assume that in any period a merchant's goods could be *unverifiably* lost with probability $\lambda \in (0,1)$, where it is intended that λ is relatively small number. We first consider how the introduction of such uncertainty affects the viability of a collective punishment strategy based on permanent exclusion, as in Greif (1993), and then how the situation changes when compensation payments are re-introduced.[36] To allow for a meaningful comparison with the model without trading uncertainty however, it will first be useful to enrich Greif's original model so that the level of trade achieved in equilibrium is determined endogenously, rather than fixed exogenously.

3.1 Endogenous Levels of Trade

In Greif (1993), the gross value of trade realized by a merchant-agent relationship in any period is fixed exogenously at γ. This means that trade is either fully efficient, i.e. when $W^* \leq \gamma - \kappa$, or that no trade occurs at all. To allow for different levels of trade to be achieved in equilibrium, we

betel nuts lost to Indian pirates.

[34] Letter 1 in Goitein (1973) provides a clear illustration of this.

[35] Letter 1 of Goitein (1973) concerns a merchant who had withdrawn cooperation from a former agent over a shipment of brazilwood which had gone astray, and for which the merchant had not received compensation. Letter 36 clearly shows that traders acting as agents could be held accountable for losses due to 'shipwreck and other misfortunes.' See also Goitein (1954).

[36] Greif (2006), footnote 45, p. 73, suggests a more complex model in which revenue is a random variable $\widetilde{x}$ observed by the agent, and the merchant learns the actual realization of $\widetilde{x}$ with positive probability. The additional realism achieved over our simpler approach would not appear to repay the extra costs in complexity.

will now think of $\gamma \geq 0$ as an input into the trading relationship supplied by the merchant (i.e. the amount of capital invested or goods shipped to the agent), and assume that the gross gains from trade are determined by a function $f(\gamma)$. The function $f(\cdot)$ is assumed nonnegative with $f(0) = 0$, twice continuously differentiable, and strictly concave. $f(\cdot)$ thus achieves a maximum at a unique value $\overline{\gamma} > 0$ where $f'(\overline{\gamma}) = 0$, and we assume $f(\gamma) > \gamma$ for all $\gamma \in (0, \overline{\gamma}]$. Hence, there are diminishing marginal returns to investing in the trading relationship in any period, and the efficient level of investment is $\overline{\gamma}$.[37]. We will also assume, as seems natural, that the profit an agent can obtain from cheating a merchant is an increasing function of the level of investment chosen in any period. We specify this function by $\alpha(\gamma)$, with $\alpha(\cdot)$ nonnegative and $\alpha(0) = 0$, twice continuously differentiable, concave and $f(\gamma) \geq \alpha(\gamma)$ for all $\gamma \in [0, \overline{\gamma}]$. Finally, we assume $\kappa > f(\gamma) - \alpha(\gamma)$, for all $\gamma \geq 0$.

From Proposition 1 it is immediate that the minimum wage rate required to induce cooperation from agents in every period is now given by

$$W^*(\gamma) = [T - \delta\tau H]\,\alpha(\gamma), \tag{20}$$

and is strictly increasing in γ.[38] In order to obtain results on the levels of trade achieved in equilibrium, it will be useful to have the following definition. We will say that $f(\cdot)$ is "more concave" than $\alpha(\cdot)$ on $(0, \overline{\gamma})$ if the ratio $r_f = \frac{-f''}{f'}$ exceeds the ratio $r_\alpha = \frac{-\alpha''}{\alpha'}$ everywhere on $(0, \overline{\gamma})$.[39] We may then state the following proposition.

Proposition 4 *If $r_f > r_\alpha$, the efficient level of trade $\overline{\gamma}$ cannot be sustained in equilibrium.*

Proof. A merchant's per-period payoff in a stationary equilibrium is given by $V^M = f(\gamma) - W^*(\gamma)$. So a merchant's profit is maximized by choosing a level

[37] See Greif, Milgrom and Weingast (1994) for a similar specification of a 'trading technology'.

[38] That is, $W^*(\gamma)$ solves $V_h(W) = \alpha(\gamma) + \delta V_c^u$. To simplify the exposition we have now assumed that $\overline{w} = 0$, so $V_c^u = 0$. This is without further loss of generality. Following Greif (1993), we will also assume throughout the following discussion that trade is individually rational for merchants at the equilibrium levels of W and γ.

[39] This is just the standard definition of the coefficient of absolute risk aversion (c.f. Mas Colell, Whinston and Green, 1995, p. 191). From now on the statement '$r_f > r_\alpha$' will subsume the qualifying condition 'everywhere on $(0, \overline{\gamma})'$.

of investment γ^* such that $f'(\gamma^*) = \frac{\partial W^*(\gamma)}{\partial \gamma}$, or $f'(\gamma^*) = [T - \delta\tau H]\,\alpha'(\gamma^*)$. $r_f > r_\alpha$ implies that $\alpha'(\overline{\gamma}) > 0$, so we must have $\gamma^* < \overline{\gamma}$. ■

The assumption that $f(\cdot)$ is more concave than $\alpha(\cdot)$ implies that, over the relevant range, the gains obtained from cheating increase more rapidly than the gains from cooperation, $f(\gamma)$.[40] Thus if we choose the natural specification $\alpha(\gamma) = \gamma$, so that what the agent obtains from cheating is the merchant's investment, the efficient level of trade cannot be achieved. Alternatively, if we specify the gains from cheating as a function $\alpha f(\gamma)$, $\alpha \in (0, 1]$, then $\alpha'(\overline{\gamma}) = 0$ and the efficient level of investment will be obtained in equilibrium. Roughly speaking, inefficient investment occurs when the gain from cheating is an increasing function of the merchant's investment, but some level of cooperation between the merchant and agent is still required to realize the full value of trade $f(\gamma)$. This formulation would appear to be most consistent with Greif's (1993) requirement that cheating entail an efficiency loss. In this case, agents' incentive constraints imply that $\overline{\gamma}$ cannot be achieved, since over the range $[\underline{\gamma}, \overline{\gamma}]$, increases in merchant investment require proportionately larger increases in the efficiency wage to offset the enhanced incentives for cheating.

3.2 Trading Uncertainty and Exclusion

We now introduce trading uncertainty into the model, and consider the punishment strategy which specifies that following any *unverifiable* report of losses by an agent, the agent is fired and never rehired by any merchant. Since merchants cannot distinguish between unverifiable reports of losses and actual cheating, neither can the collective punishment strategy.[41]

To fix the one-period extensive form, assume that at the beginning of any period each merchant sends his goods to an agent, and the goods are lost in transit with probability λ. If the agent receives the goods, he decides whether to cheat or be honest given the wage rate $W_\lambda(\gamma)$ he has been offered. At the end of the period, the agent either returns $f(\gamma) - W_\lambda(\gamma)$ to the merchant, or

[40] The relevant range is $[\underline{\gamma}, \overline{\gamma}]$, where $\underline{\gamma} < \overline{\gamma}$ is defined by $f'(\underline{\gamma}) = \alpha'(\underline{\gamma})$.

[41] Hence, as in the model of Green and Porter (1984), punishment is not triggered by the inference that an agent has cheated, rather it is a self-enforcing reaction to a report of losses required to sustain the equilibrium incentives.

reports that the goods have been lost. In the latter case the agent obtains a payoff of either 0 or $\alpha(\gamma)$, and is subject to the collective punishment strategy.

In order to analyze the multi-period game, we first modify Greif's model by assuming that when an agent is fired for cheating, he can be immediately replaced by another agent, so that the total number of 'honest' agents remains constant over time. That is, we suppose that merchants hire agents exclusively from a pool of 'insider' agents, but that the pool of 'insiders' can be replenished from a large (i.e. effectively infinite) pool of 'outsider' agents when required.[42] It is in merchants' interests to designate a pool of 'insiders', as this allows trade to be sustained by a collective punishment strategy when trade supported by bilateral punishment strategies is not possible, and results in lower wage payments otherwise (Greif, 1993, Section 4). And it is easy to see that hiring only insider agents is a self-enforcing strategy for merchants - since an outsider never expects to be rehired if (unexpectedly) employed by a merchant, a higher wage is required to prevent him from cheating.[43]

The assumption of agent replacement is needed because with trading uncertainty, in every period t an expected number λA_t of agents will gain a reputation for cheating and be excluded from further trade (where A_t is the number of remaining honest agents in period t). So the number of agents remaining in the game will decrease period-by-period, until eventually too few honest agents are left to sustain mutually beneficial trade.[44] This makes the equilibrium path of play under exclusion strategies nonstationary and extremely complex, and comparisons with play under compensation strategies meaningless. However, it can shown that the assumption of agent replacement leads to the minimum wage and the maximum amount of trade being sustained in equilibrium for any $A \geq M$, so the propositions below remain

[42] The assumption of 'insiders' and 'outsiders' is needed in order to maintain $h > 0$; otherwise the efficiency-wage model is degenerate. Goitein (1973), p.13, notes that the Maghribis often freed former bond-servants and slaves to become respectable merchants and agents in their own right, illustrating one means by which new members were added to the coalition.

[43] See Proposition 1. Merchants would collectively prefer to fix the number of insider agents at $A = M$, since this results in the lowest equilibrium wage and the highest level of trade. We will allow for any value of $A \geq M$, however.

[44] When $A_t < M$, trade breaks down under our specification of the equilibrium strategies. See further below.

true in the absence of this assumption.[45]

Given this specification, the expected lifetime utility of an employed honest agent at the beginning of any period (i.e. before the trade risk uncertainty is resolved), is given by

$$V_{h\lambda} = (1-\lambda)\left[W_\lambda(\gamma) + (1-\tau)\delta V_{h\lambda} + \delta\tau V^u_{h\lambda}\right], \tag{21}$$

for any level of investment γ chosen by the merchant. Since an agent decides to cheat or be honest after the trade risk uncertainty is resolved, for given values of λ and γ the lowest wage for which an agent's best response is to be honest in any period is then,

$$W^*_\lambda(\gamma) = \left[T_\lambda - (1-\lambda)\delta\tau H\right]\alpha(\gamma), \tag{22}$$

where $T_\lambda = 1-(1-\lambda)\delta(1-\tau)$. Comparing this with equation (20) above, it is immediate that for a given choice of γ, $W^*_\lambda(\gamma) > W^*(\gamma)$ whenever $\lambda > 0$, and $\frac{\partial W^*_\lambda(\gamma)}{\partial\lambda} > 0$.[46] In addition, we have the following proposition.

Proposition 5 *If $r_f > r_\alpha$, for any value of $A \geq M$, the equilibrium level of investment under trading uncertainty is less than the equilibrium level of investment under bilateral perfect information.*

Proof. Merchants will now choose the level of investment γ^*_λ to maximize $V^M_\lambda = (1-\lambda)\left[f(\gamma) - W^*_\lambda(\gamma)\right]$, requiring that $f'(\gamma^*_\lambda) = \left[T_\lambda - (1-\lambda)\delta\tau H\right]\alpha'(\gamma^*_\lambda)$. Since $[T_\lambda - (1-\lambda)\delta\tau H] > [T - \delta\tau H]$, $\forall\lambda > 0$, $\gamma^*_\lambda < \gamma^*$ follows from the fact that $\frac{\partial}{\partial\gamma}\left(\frac{f'(\gamma)}{\alpha'(\gamma)}\right) < 0$, $\forall\gamma \in (0,\overline{\gamma})$. This in turn follows from the assumption that $r_f > r_\alpha$ everywhere on $(0,\overline{\gamma})$. ■

The addition of trading uncertainty means that agents must be paid a higher efficiency wage for any choice of the level of investment, to compensate them for the risk of being innocently punished when a merchant's goods

[45] This is because the expected lifetime utility of an employed honest agent decreases over time as the probability of trade collapsing increases, while the one-period gain from cheating is constant. Hence agents must be paid a higher wage to compensate for this risk. For example, when $A = M$, the equilibrium wage in the game with agent replacement is given by (22) below with $H = h = 1$, i.e. $[1-\delta(1-\lambda)]\alpha(\gamma)$. Without replacement the equilibrium wage is $[1-\delta(1-\lambda)^M]\alpha(\gamma)$. The latter exceeds the former for any level of γ and $M > 1$.

[46] Similarly, it is easily checked that $W^*_{c\lambda}(\gamma) > W^*_c(\gamma)$ whenever $\lambda > 0$, and $\frac{\partial W^*_{c\lambda}}{\partial\lambda} > 0$.

are lost in transit. So it is not surprising that this should result in a lower value of trade being chosen in equilibrium, once this risk is included in the model.[47] Further, as remarked above, in the model without agent replacement, eventually there will be fewer honest agents remaining in the game than there are merchants, so the collective punishment strategy specified in Greif (1993) breaks down. Our equilibrium strategies specify a reversion to autarky when this happens.[48] Although more complex punishment strategies can be devised to slow down this process, after a sufficient amount of time enough agents will have been accused of cheating so that cooperative trade supported by exclusion strategies cannot be sustained.[49]

3.3 Compensation with Trading Uncertainty

Under the punishment strategy requiring that agents pay compensation, even agents who have not cheated will need to pay C_0 in the event that a merchant's goods are lost.[50] So the expected equilibrium payoff from following an honest strategy (before the trade risk uncertainty is resolved) is given by,

$$V_{h\lambda} = (1-\lambda)W_\lambda(\gamma) - \lambda C_{0\lambda}(\gamma) + (1-\tau)\delta V_{h\lambda} + \tau\delta V_{h\lambda}^u. \tag{23}$$

Since compensation will paid in equilibrium, agents are never fired and remain employed by their current merchant with probability $1-\tau$. For any level of investment γ chosen by the merchant, cheating results in an immediate gain of $\alpha(\gamma)$, so for an agent to prefer being honest over cheating and paying compensation immediately, we must have

$$W(\gamma) + (1-\tau)\delta V_{h\lambda} + \tau\delta V_{h\lambda}^u \geq \alpha(\gamma) - C_0(\gamma) + (1-\tau)\delta V_{h\lambda} + \tau\delta V_{h\lambda}^u, \tag{24}$$

[47] Whether $W_\lambda^*(\gamma_\lambda^*) \lesseqgtr W^*(\gamma^*)$ is indeterminate, however, in the absence of stronger assumptions on the forms of $f(\cdot)$ and $\alpha(\cdot)$.

[48] See footnote 13 above. This is arguably inefficient now that these subgames are reached with positive probability. We could instead specify a reversion to bilateral trading strategies (see Greif, 1993, Proposition 3), whenever this is possible.

[49] An obvious alternative is finite punishment strategies. No evidence for these, or any of the more elaborate punishment strategies one can think of, is provided in the historical literature, so we will not pursue them further here.

[50] We will simply assume that agents are capable of making such payments on average. We could follow Baliga and Evans (2000) or Kletzer and Wright (2000), for example, and assume that agents receive 'endowments' in each period, and that these endowments are sufficient to cover the required expenditures.

or $C_{0\lambda}(\gamma) \geq \alpha(\gamma) - W_\lambda(\gamma)$. In order for an agent to prefer paying compensation immediately over becoming unemployed forever we require

$$-C_{0\lambda}(\gamma) + (1-\tau)\delta V_{h\lambda} + \tau\delta V_h^u \geq 0, \tag{25}$$

or $C_{0\lambda}(\gamma) \leq \frac{V_{h\lambda}-(1-\lambda)W_\lambda(\gamma)}{(1-\lambda)}$. By following the steps in the proof of Proposition 2, it is easily established that in equilibrium $\widehat{C}_{0\lambda}(\gamma) = \alpha(\gamma) - \widehat{W}_\lambda(\gamma)$, $\widehat{C}_{1\lambda}(\gamma) = V_{h\lambda}^u$, and $V_{h\lambda}(\widehat{W}_\lambda(\gamma)) = \alpha(\gamma)(1-\lambda)$. It follows immediately that for any choice of γ, $\widehat{W}_\lambda(\gamma) = W_\lambda^*(\gamma)$ and $\widehat{C}_{1\lambda}(\gamma) < \alpha(\gamma)(1-\lambda)$.[51] But the equilibrium value of trade, $\widehat{\gamma}_\lambda$, achieved with compensation punishment strategies will in general differ from that obtained under exclusion strategies.

Proposition 6 *If $r_f > r_\alpha$, for any value of $A \geq M$, the equilibrium level of investment in the compensation strategy equilibrium under trading uncertainty exceeds that achieved in the exclusion strategy equilibrium under trading uncertainty.*

Proof. A merchant's expected per-period payoff in the compensation equilibrium is,

$$V_\lambda^M(\gamma) = (1-\lambda)\left[f(\gamma) - \widehat{W}_\lambda(\gamma)\right] + \lambda\widehat{C}_{0\lambda}(\gamma). \tag{26}$$

Substituting $\widehat{C}_{0\lambda}(\gamma) = \alpha(\gamma) - \widehat{W}_\lambda(\gamma)$, and maximizing with respect to γ yields,

$$(1-\lambda)\left[f'(\widehat{\gamma}_\lambda) - (T_\lambda - (1-\lambda)\delta\tau H)\,\alpha'(\widehat{\gamma}_\lambda)\right] + \lambda\alpha'(\widehat{\gamma}_\lambda)\left[1 - (T_\lambda - (1-\lambda)\delta\tau H)\right] = 0. \tag{27}$$

Since the second addend on the LHS of (27) is always positive for $\lambda > 0$ and $\widehat{\gamma}_\lambda \leq \overline{\gamma}$, this requires $f'(\widehat{\gamma}_\lambda) < (T_\lambda - (1-\lambda)\delta\tau H)\,\alpha'(\widehat{\gamma}_\lambda)$, which from our previous argument implies $\widehat{\gamma}_\lambda > \gamma_\lambda^*$. It is straightforward to show that $\widehat{\gamma}_\lambda < \overline{\gamma}$ for all $\lambda < 1$. ■

As in the model without trading uncertainty, the two types of collective punishment strategy provide for the same efficiency wage to be paid to agents for a given value of γ. However, the fact that compensation must now be paid by agents with probability λ in any period, and that the equilibrium compensation payment is an increasing function of γ, means that a higher

[51] Demonstrating that $\widehat{W}_\lambda(\gamma) < \widehat{W}_{c\lambda}(\gamma)$ also follows easily from the arguments presented in Proposition 2.

level of investment can be sustained in the equilibrium with compensation, at least when cheating entails an efficiency loss. Hence when $r_f > r_\alpha$, $\widehat{W}_\lambda(\widehat{\gamma}_\lambda) > W^*_\lambda(\gamma^*_\lambda)$, i.e. agents are paid a higher wage in the compensation strategy equilibrium.

In addition, when the pool of available agents is finite, the collective punishment strategy specifying permanent exclusion from trade eventually breaks down once a sufficient number of agents have acquired a reputation for cheating, and the long-run result is autarky. This problem clearly does not beset the punishment strategy requiring incentive-compatible compensation payments to be made. Since all agents will choose to pay compensation in equilibrium (whether innocent or guilty), the trading institution does not break down in the face of bilateral imperfect information. Hence, as claimed in Section 2, it is a more efficient institution in a world of imperfect information or imperfect monitoring in which mistakes or transgressions were likely to occur.

4 Partnerships and Formal Friendships

A final issue with the model of Maghribi agency relations described in Section 2 is that it does not appear to present a very accurate picture of the Maghribi's actual organization. Greif (2006), p.285, writes for instance,

> "*The Maghribi traders were by and large merchants who invested in trade through horizontal agency relations. Each trader served as an agent for several merchants while receiving agency services from them or other traders. ... The horizontal social structure of the Maghribis is also reflected in the forms of business associations through which they established agency relations. They mainly used partnership and "formal friendship." ... In a "formal friendship" two traders operating in different trade centers provided each other with agency services without pecuniary compensation.*"

This structure of trade through partnerships and "formal friendships" is not that specified in the efficiency wage model.[52] The Maghribi's "punishment strategies" were also more elaborate than those allowed for by Greif's model, as noted above.[53] It is straightforward, and instructive, to capture some of these elements of the Maghribi organization in a simple model.

4.1 A Simple Model of "Formal Friendships"

Assume now that each trader acts as both a merchant and an agent in a single merchant-agent relationship ("formal friendship") in each period.[54] Merchants still can't cheat agents, so the honest strategy is for the "trader as agent" to refrain from embezzling the "trader as merchant's" goods to obtain a one-period payoff of α.[55] Recall that κ is the payoff of a merchant who acts on his own behalf, i.e. neither employs an agent nor is employed as an agent. For a given wage W, an honest trader's lifetime expected utility can be written,[56]

$$V_h^T = \frac{(\gamma - W)}{(1-\delta)} + \frac{W}{(1-\delta)} = \frac{\gamma}{(1-\delta)}. \tag{28}$$

The punishment for cheating is that the trader can no longer hire agents (since they will cheat him free from collective punishment), and can no longer be hired as an agent. Hence a trader who has cheated is 'ostracized' and receives his reservation utility κ in each period (we maintain the assumption that $\overline{w} = 0$ from the previous section). The profit from cheating, when cheating is perfectly monitored and all traders adhere to the punishment

[52] See also Goitein (1967), Chapters III.B.1-III.B.4. Goitein (1987), p.184, notes that instances of the payment of wages or commissions to agents are "*next to nonexistent*" in the Geniza records, and that, "*first and foremost, [agency] services were reciprocal.*"

[53] In particular, when an agent accused of cheating operated as a merchant, he could in turn be cheated by his own agents without their being subject to collective punishment. See Greif (2006). p. 283.

[54] This is not the same as assuming the purely 'bilateral' trading relationships considered in Greif (1993), Section 4.

[55] Since it follows immediately from (28) below that the efficient level of investment $\overline{\gamma}$ will be chosen by each trader acting as a merchant, we simplify the exposition by reverting to the model of Section 2 in which the values of α and γ are exogenously fixed.

[56] Observe that we are no longer assuming an exogenous probability of merchants firing agents, i.e. we have set $\tau = 0$.

strategy, is

$$V_c^T = (\gamma - W) + \alpha + \frac{\delta\kappa}{(1-\delta)}. \tag{29}$$

That is, the "trader as merchant" receives $\gamma - W$ and the "trader as agent" obtains α from cheating his partner in the formal friendship. The lowest wage required to ensure that cheating is not profitable is then,

$$W^* = Max\left[0, \alpha - \frac{\delta(\gamma-\kappa)}{(1-\delta)}\right]. \tag{30}$$

Note that $W^* = 0$ is a possibility,[57] as seems to have been the custom in formal friendship trading relationships.

According to the Maghribi's practice, described in Section 2 above, any trader who enters into a formal friendship with a trader who has cheated in the past can cheat that trader without facing the threat of future collective punishment. Since this is always profitable, even in the presence of small switching costs, a cheater's best response is also to cheat in such relationship, so they will not be formed in the first place. This is because the honest trader can expect to earn at most $\alpha + \frac{\delta\gamma}{(1-\delta)}$ from such a trading relationship, which is less than it can earn from establishing a formal friendship with another honest trader. Thus for any wage rate weakly exceeding W^*, cheating is unprofitable and the collective punishment is self-enforcing.[58]

The only unresolved question is why a trader should *fire* (or break off a formal friendship trading relationship) , as opposed to *not hire*, a trader who has cheated in the past. But the argument just outlined above works equally well here also. A trader who is cheated in period t can cheat his period t trading partner in period $t+1$ free from any threat of future collective punishment. Given this, the trader who has cheated in period t will cheat again period $t+1$. So for switching costs which are not too large, the cheated trader will prefer to dissolve the current relationship and search for an honest trading partner.

What role, then, does the Maghribi's compensation scheme have to play in this context? Presumably it allows players who would otherwise be permanently ostracized to return to the equilibrium path of play, avoiding the

[57] Specifically, $W^* = 0$ whenever $\delta \geq \frac{\alpha}{\alpha+\gamma-\kappa}$, where $\frac{1}{2} < \frac{\alpha}{\alpha+\gamma-\kappa} < 1$ by assumption.

[58] This was not true in the one-sided efficiency wage model considered in Section 2, because in that model merchants had no opportunities to profitably cheat agents who had cheated them in the past.

inefficiencies associated with following an exclusion strategy in the presence of trading uncertainty, as in Section 3. When we introduce such trading uncertainty into the model, it is easily checked that the expected lifetime utility of following the honest strategy is then,

$$V_{h\lambda}^{T} = \frac{(1-\lambda)\gamma + \lambda\frac{\delta\kappa}{1-\delta}}{1-\delta(1-\lambda)}. \tag{31}$$

Hence

$$W_{\lambda}^{*} = Max\left[0, \alpha - \delta\left(\frac{(1-\lambda)\gamma - \kappa}{1-\delta(1-\lambda)}\right)\right], \tag{32}$$

so as in the model of Section 3, a higher equilibrium wage may be required to enforce cooperation in the presence of trading uncertainty.

Honest agents are now subject to collective punishment in each period with probability λ. If the pool of available agents is not infinite (i.e. if we do not assume agent replacement), under exclusion strategies all traders will eventually be ostracized. The Maghribi's compensation scheme again solves this problem. By following the steps in the proof of Proposition 2, it is easily established that the maximum compensation that a first-time cheating agent can be induced to pay is $\widehat{C}_{0\lambda} = \delta\left(\frac{(1-\lambda)\gamma-\kappa}{1-\delta}\right)$. From the condition $\widehat{W}_{\lambda} \geq \alpha - \widehat{C}_{0\lambda}$, we then obtain

$$\widehat{W}_{\lambda} = Max\left[0, \alpha - \delta\left(\frac{(1-\lambda)\gamma - \kappa}{1-\delta}\right)\right]. \tag{33}$$

Following the construction of Proposition 2 it is immediate that $\widehat{C}_{1\lambda} = \frac{\widehat{C}_{0\lambda}}{\delta}$.

In the model *with* agent replacement, the two types of collective punishment strategy no longer provide for the same efficiency wage to be paid to agents in equilibrium, at least when $W_{\lambda}^{*} > 0$. Compensation punishment strategies allow for (weakly) lower wages, and higher trader welfare, in equilibrium because they eliminate the risk that traders acting as agents will be ostracized when a merchant's goods are inadvertently lost in transit. Since traders' expected payoffs in a formal friendship relationship are independent of both the level of the wage and the compensation payment, eliminating this risk results in strictly higher equilibrium payoffs.[59] In the model *without* agent replacement, of course, exclusion strategies eventually eliminate

[59] The expected lifetime utility of following the honest strategy with compensation strategies is $V_{h\lambda}^{T} = \frac{(1-\lambda)\gamma}{1-\delta}$. This exceeds (31) whenever $(1-\lambda)\gamma > \kappa$, which is required for trade to be individually rational.

all trading partners, so incentive-compatible trade cannot be sustained, in contrast to the game with compensation strategies.

In this simple model of formal friendships, compensation does not play the key role in sustaining incentives to follow the equilibrium strategies that it does in the "one-sided" efficiency wage model. This is because a formal friendship trade relationship is more like the Prisoners' Dilemma model of merchant trade studied, for example, by Milgrom, North and Weingast (1990), in which both parties have opportunities to profitably cheat their current trading partner.[60] Compensation still has a crucial role to play, however, in permitting incentive-compatible trade to continue in the face of trading uncertainty or bilateral imperfect information.

5 Conclusion

In their well-known paper on the medieval merchant guilds, Greif, Milgrom and Weingast (1994), p. 746, write:

> "*A comprehensive analysis of a contract enforcement institution must consider why the institution was needed, what sanctions were to be used to deter undesirable behavior, who was to apply the sanctions, how the sanctioners learned or decided what sanctions to apply, why they did not shirk from their duty, and why the offender did not flee to avoid the sanctions.*"

The purpose of this paper has been to attempt to fulfill these criteria with respect to the organization of trade between the early Mediterranean Maghribi traders. Greif's (1993) model of trade amongst the Maghribis represented an attempt to find 'plausible' punishment strategies which did not rely on second (or higher)-order punishments to sustain cooperation. His equilibrium strategies, however, required either the assumption of zero agent switching costs, or multilateral perfect information. We have argued that neither of these assumptions is justified by the historical evidence, leading

[60] Compensation imposed by a Law Merchant is required in Milgrom, North and Weingast (1990) because in their model traders only ever meet once, so a cheated trader requires an incentive to impose sanctions when this is a personally costly activity. See also Aoki (2001), Chapter 3.3, for an exposition of this model.

to a reconsideration.[61] This has led us to develop two different models of Maghribi trade relationships which bring into play, in an essential way, historical features of the Maghribi's organization which had no role in Greif's own analysis.

Our 'compensation-based' equilibrium strategies would seem to more accurately reflect Maghribi practices, and have a number of desirable properties. They utilize the Maghribi's actual 'punishment strategies' to sustain a cooperative equilibrium, and reveal the crucial importance of discouraging merchants from making false declarations of cheating. They also explain how the Maghribis avoided the inefficiencies involved in permanently ostracizing valuable trading partners in the face of uncertainty or bilateral imperfect information, while still providing incentives for cooperation.

An important part of the literature on infinitely repeated games has been concerned with the issue of the credibility of multi-level punishment strategies when punishment is costly to both the 'cheater' and the 'cheated'.[62] The concept of "renegotiation-proofness", taken to its logical limits, implies that such punishments will frequently not be viable, because rational players will wish to renegotiate if they (unexpectedly) reach a subgame in which they are called on to implement them. Farrell (2000) puts the argument well:

> "*If, indeed, players can efficiently coordinate on an equilibrium, what would really happen after (out of equilibrium) one player cheated? If the pre-specified punishment would hurt the innocent as well as the guilty, then we might well expect renegotiation, perhaps in the simple form of an agreement to ignore the transgression "this time". Such undiscriminating punishments may therefore lack credibility, even if they are subgame perfect.*"

[61] Greif himself is sharply critical of analyses (such as Milgrom, North and Weingast, 1990), employing 'microanalytic' models which identify theoretical possibilities but do not establish that they "*correspond to a historical reality.*" Especially when such analyses "*do not make use of relevant historical details.*" See Greif (2006), Section 10.3.

[62] See in particular Farrell and Maskin (1989) and Bernheim and Ray (1989). The equilibrium strategies described in Section 2 are 'weakly renegotiation-proof' according to at least one definition, as observed in Proposition 3. Baliga and Evans (2000) show how strongly renegotiation-proof equilibria can be constructed in two-player repeated games when side-payments (i.e. compensation payments) are permitted.

Other authors have argued that the Farrell and Maskin (1989) concept of (weak) renegotiation-proofness is too strong, and takes the logic of subgame perfection beyond its reasonable limits.[63] Despite (or perhaps because of) the inconclusiveness of this debate, the Maghribi traders seem to have resolved the problem for themselves over one thousand years ago. Instead of demanding that traders implement costly punishments, requiring reinforcement by 'cheaters' in the form of second-level punishments (and so on), they devised a more robust and more efficient institution. The Maghribi's compensation scheme gave merchants positive incentives not to renegotiate with cheaters, and gave agents accused of cheating a means of reestablishing their reputations, hence avoiding the costs of permanent ostracism. As such, the Maghribi's organization may have foreshadowed developments in game theory which took another thousand years to emerge.

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[63] See, for example, Binmore (1997), Ch. 3, Abreu and Pearce (1991) and Rabin (1991). Rabin summarizes the argument succinctly in stating that, "*if you cheat, you cannot renegotiate as if you were negotiating for the first time.*"

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