A Comparison of Two Historical Trader Societies – An Agent-Based Simulation Study of English East India Company and New-Julfa

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Abstract. In this paper, we study the English East India Company (EIC) and Armenian traders of New-Julfa (Julfa) that were active during 17th and 18th centuries. Both were successful trading cooperatives that relied on different institutional parameters and mechanisms to coordinate their activities. In this work, we explore a selection of those aspects (five of them): a) societal mortality rate, b) nature of the system in attracting workforce (open vs. close), c) existence of adjudication process, d) payment scheme, and e) punishment. To study effects of these attributes on system behaviour, we systematically modify these attributes to create a total of 10 hypothetical systems, two of which mirror characteristics of the EIC and Julfa systems. By doing these modifications, we study which of these systems are successful in improving system performance in terms of a) identifying cheaters, b) improving trading skills of agents, c) making more profit for the organisation, and d) deterring agents from cheating. A central insight of the simulation was the impact of substantial profit sharing on trader cooperation (i.e. more profit sharing resulted in lowered cheating). Moreover, our results show that Julfa had a lower number of cheaters despite having an open workforce to attract employees, thus making it more profitable and robust to changes in workforce characteristics (i.e. using an open workforce society).

Keywords: Principal-Agent problem · Armenian Traders of New-Julfa · Agent Based Modelling · English East India Company · Game theory · Social simulations · Historical trading.

1 Introduction

One of the issues faced by international companies in a collaborative and distributed environment is limited information transparency, often leading to information asymmetry. Nowadays, international companies try to overcome this problem using real-time information infrastructures. Challenges associated with such a class of problem are commonly referred to as the "*principal-agent problem*" [14], wherein two parties are engaged in a deal where an *agent* should pursue his *principal*'s (Master's) benefits by performing actions, but these actions are hard to monitor. Particularly in long distance trades that we consider in this work, the power delegation to agents (i.e. access to company resources) and absence of transparency are some reasons for using company resources for self-interests. Henceforth, we refer to any selfish behaviour that imposes some costs to the principal as ***cheating***.

Note that, agents are important organisation resources because their gradual improvement of skills leads to a company profitability enhancement. On the other hand, retain skilled agents cheating impose coasts to the organisation. We study these effects, by modelling some aspects of *English East India company* (EIC) and *Armenian merchants of New-Julfa* (Julfa). These societies were long-distance traders that pursued their benefits by delegating some rights to agents in remote places. They were successful in trade, despite their different demographic and institutional characteristics, namely workforce society, punishment and reward, and mortality rate (we use institutions as a term reflecting rules and norms in organisations [17]). The reason for choosing these societies with these characteristics lies in extensive studies performed by historians about them that provides insights into their institutions, their differences in managing their own societies, and their awareness about each other's policies. What makes the comparison of both systems appealing is their evident co-existence on the Indian subcontinent, with EIC managers identifying the Julfa traders as superior. So, EIC granted Julfans same privileges as British merchants to "alter and invert the ancient course of their trade to and from Europe" [2]. This study aims to unlock some of the secrets of this *ancient course*.

We employ agent-based simulation to study the two societies. While prior work has investigated other trading societies (e.g. Maghribi and Genoese) [6], our work here is quite different in characteristics and also considers different societies. The rest of this paper is organised as follows: Section 2 takes a comparative look at EIC and Julfa. Section 3 discusses how these systems are abstractly modelled and the reason behind chosen parameters. In Section 4 results of simulation are presented and discussed. Finally, Section 5 sums up the findings of the model and proposes future directions.

2 Review of Systems

In this section we provide a brief background of the two systems and then compare them with respect to five characteristics of EIC and Julfa. A brief review of these characteristics is presented in Table 1. EIC was formed in 1600 based on monopoly of trade between Asia and Britain, granted by Queen Elizabeth I [20] and was active until middle of the 19^{th} century. One of the first problems EIC faced was finding experienced agents to perform long-distance trades. So, they used an *open* workforce scheme for subsequent years where any worker from Britain was allowed to join. On the other hand, Armenian merchants of New-

Julfa were originally from Old-Julfa in Armenia, and they had inheritance rules that created strong family bonds [12], and used informal institutions to control society. These kinds of social bonds and sharing the same background were some reasons of having a *closed* workforce society in Julfa. Note that, both societies hired males as agents (we focus on men in societies).

Moreover, some relaxations of EIC monopoly between 1660 and 1700 that followed by the establishment of *Company of Scotland* in 1695 [5], persuaded the company to pay low nominal salaries[1] and grant agents privilege of private trade (right of trade in the intra-Asian market) [10]. As a result, EIC agents sought other sources to increase their income and counted on private trade as their real salary [10]. In Julfa masters used commenda contract (an open-ended contract with substantial profit sharing) where a proportion of profit (around 30%) was shared with traders [12]. The mortality rate of EIC was higher. A newcomer to the system on average worked not even past his 30s (i.e. 15 years of service time) [10]. On the other hand, there are no discussions about such a problem for Julfan people, neither in their letters nor in historical contexts.

Table 1: System Specification based on EIC and Julfa Societies

Characteristics	EIC	Julfa
Nature of the workforce	Open	Closed
Payment design	Private trade + living costs	Commenda + living costs
Mortality rate	High (H)	Low (L)
Adjudication chance	No	Yes
Punishment	Dismissal + unutilised bond	Boycotting, losing family or pay costs + interest

Julfans had autonomy inside and outside of Iran and established churches of their own in their frequently visited cities and used them as a source for storing (archiving) and transmitting information [2]. Moreover, they had two kinds of institutions for settling disputes, the assembly of merchants and portable courts. We call the process of going through evidences and decision making the *adjudication* process. This process was rigorous and identified cheaters effectively. However, in EIC managers felt that a large number of cheaters were present in the system despite limited reports [3]. This could have been from colluding together or increased tolerance in managers towards cheating to avoid hiring unqualified people [3]. However, this insufficient monitoring introduced a surprising firing pattern (i.e. more experienced merchants were fired in higher propositions despite their higher income[2]). So, in EIC subjective means for identifying cheaters was employed without any adjudication process [11]. This firing scheme introduces likelihood of punishment for a bad performance without any evidences for cheating.

On the other hand, EIC discouraged employees from cheating by asking them to provide a bond of at least £500 [11] and punished them by dismissing them in

[1] £5 to £40 versus £50 in Britain
[2] Around £1000 see Table 1-3 of [11].

case of suspicion. However, in Julfa one of the frequently used ways of punishment was asking a cheater, or his core or extended family to pay back the incurred costs, otherwise they would be boycotted from future trades engagement. The evidence suggests that these consequences were harsh with a merchant noting to his brother: "I would rather chuse [sic] to dye [sic], than for them to [blot my] name out of the list [2]."

In the closed society of Julfa, there were several means of monitoring such as discussing merchants' behaviour expressed through letters written between different people, trustworthiness of other agents, and prices. For instance, we can see in one of the merchant's correspondence with his cousin (Paron Petros) which reads:

> Paron Petros, your letter from Livorno dated Atam 22 [May 11] reached us on Hamira 8 [November 23], and we became acquainted with your situation. [However] your letter was without flavor or salt [Bi Namak] (literally means "without salt") because it contained no news about purchases and expenditures. The salt in a merchant's letter is [the news about] purchases and expenditures. When you send us your next letter, be sure to write about the state o f purchases and expenditures both in Livorno and Venice, so we too can be more satisfied. [2]

"The Jullfans" also could gather information about activities of merchants using church archives or through direct contacts during meetings in local churches or chapels [2]. Finally, an agent upon his return has to hand over everything he has with him including goods, accounts, personal luggage, and clothing makes it harder to hide cheats from master [12]. These detailed communication plus their strong social relationships, convince us to assume non-cheaters followed Socrates arguments:

> ... Which is better, to live among bad citizens, or among good ones? ... Do not the good do their neighbours good, and the bad do them evil? ... And is there anyone who would rather be injured than benefited by those who live with him? [18]

As discussed above, these two societies had differences in workforce societies, payments, mortality rates, adjudication process and monitoring, and punishment (see Table 1) and we study effects of these differences in these systems using an agent-based simulation.

3 Simulation model of two systems

In this section we present a model that investigates the effects of five key attributes of aforementioned societies on *system performance*. To do so, we assume that a part of society consists of people who play a game with incomplete information wherein they decide whether to cheat or not [16]. Agents make this decision based on parameters, such as cheating income (CI), future income (FI), discount rate (α), and punishment (P). Moreover, effectiveness of institutions has an effect on their decision making. In other words, probability associated with each situation (system state) affects agent behaviour. So, agents estimate the probability of getting fired in different situations: a) cheating (pc), b) bad performance associated with cheating (ppc), and c) bad performance of non-cheaters (ppnc). Table 2 shows how agents decide about their *actual* actions based on the consequences and their estimations of their *master's suspicion* about what they did, i.e. they may not cheat but master may think they cheated based on their performance. Table 2a shows the utility obtained (punishment or reward) of each state. Table 2b shows the estimated probability of being in each state for chasing an action. The rest of the society are those who would not cheat at all for their moral, religious, or other reasons. Moreover, organisations aim at maximising profits employing different payment, punishment, and firing schemes.

Table 2: Game that potential cheaters play

(a) Punishment and Rewards

		Master's Suspicion	
		Cheat (C)	Not Cheated (NC)
Actual	C	$CI - P$	$CI + \alpha \times FI$
	NC	0	$\alpha \times FI$

(b) Associated Probabilities

		Master's Suspicion	
		C	NC
Actual	C	$pc + ppc$	$1 - (pc + ppc)$
	NC	$ppnc$	$1 - ppnc$

Algorithm 1: Organisational level

1 Identify and fire cheaters based on observations
`/* Observations is a function of agent's cheating level and chance of identification */`
2 **if** *There is no adjudication process* **then**
3   Measure performance of agents based on their experience and update their record using discount factor
4   Fire worst performers with high access, i.e. Junior merchants, senior merchants, or council members (more than 12 years experience).
5 **if** *Workfoce Society is open* **then**
6   Hire People so that the population is stable
7 **else**
8   Hire all agents aged 15
9 Current Capital $\leftarrow \sum_{\forall Agents} Master's\ capital$ in hand of agents
10 ROR $\leftarrow$ Current Capital / Old Capital
11 Old Capital $\leftarrow$ Current Capital
12 Redistribute capital
`/* It takes place based on the number of newcomers, fired, and deceased agents. First, managers allocate 100 to each new agent, then the remainder of accumulated capital would be distributed among other merchants considering their current access to company capital (i.e. their associated Master's capital, see Algorithm 2) */`

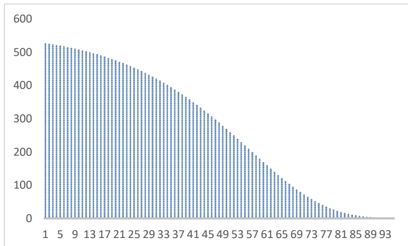
We assume that these trader societies are managed by a manager entity (an abstraction for the whole organisation). The steps performed by master, is indicated in Algorithm 1. This algorithm shows how the organisational level of a system works. The firing of cheaters takes place as a function of effectiveness of monitoring mechanisms (line 1). Monitoring depends on information about agents' behaviour available to principal that is a function of employee's loyalty.

We assume closedness of workforce society increases loyalty and information transparency due to the social bonds and informal and formal measures of information exchange. Another firing scheme is associated with lack of adjudication process (e.g. in case of EIC) and agents are judged based on their performance (lines 2-4). Then, organisations have different schemes of hiring. In open system, agents are hired to stabilise the population and in closed one all agents aged 15 years are hired (lines 5-8). The total capital in the society is the sum of capital available to all agents (line 9). Rate of Return (ROR) is the ratio of current to old capital (line 10). Then, the organisation updates its old capital for the next run (line 11) and redistributes capital based on the fired agents, deceased agents, newcomers, and agents current access to organisation's capital (line 12).

A simulation run starts with a predefined population with different ages and random priors for associated probabilities for each state. The age structure of initial population is defined in a way that it reflects the associated mortality rate. To do so, we fitted exponential function on data as suggested by [7]. Then, based on: a) population of a given year, b) percentage of deceased agents, and c) assumption that the society population did not have any trend (i.e. increasing or decreasing) recently, the number of agents in subsequent years are identified. The results of this procedure is depicted in Figure 1. For each run, which equals a year, agents update their assessments about effectiveness of different institutions, for instance the probabilities for a cheater or non-cheater to be fired. The main parameters they learn are shown in Table 3. Agents discount past estimation using 0.3 weight due to the one year lag and obsoleteness of past information. The only exception for this learning method relates to not-executed bonds. We know of no bond that were executed in EIC based on accumulated data, so agents increase their belief about ineffectiveness of these bonds with more evidence (they use a Bayesian inference for a Bernoulli distribution that assesses probability of executing bonds). For all cases agents stick with their prior if they do not observe anything new. We ascribed punishment and bonds to contract form so: a) in commenda, identified cheaters are punished based on the cheating (they know it once they start the contract) and b) in private trades, cheaters are dismissed and the bond would be paid back to them (they learn this paying back by observation). Adjudication impacts excessive penalty for cheating, i.e. a court can penalise cheaters more than their cheating.

Table 3: Punishment, Reward, and Learning

Parameter	Learning means	Note
Future income	Asking other agents	
Chance of being punished as a cheater	Observation	Discount past parameters
Chance of getting fired without any adjudication process	Observation	Discount past parameters
Chance of cheating	Observation	Discount past Performance
Effectiveness of bond	Observation	Bayesian
Punishment in commenda	Contract	Revealed Cheating + Interest



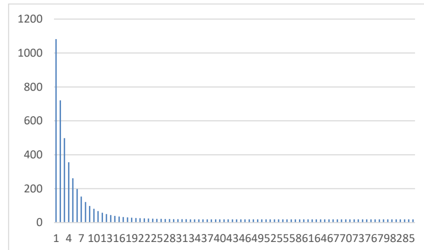


Fig. 1: Age structure for systems with a) low mortality rate and b) high mortality rate.

Algorithm 2: An agent's operational details

Increase Age by 1 year, die randomly considering mortality rate for age, to be fired based on the master's policy.
if *Workforce Society is* ***open*** *and mortality rate is* ***high*** **then**
    leave work with 40% chance × assoicated mortality rate according to age
if $age >= 15$ *and not fired* **then**
    if $age \in [16, 25]$ **then** increase skill (s) by 10% of maximum attainable skill
    if *Workfoce Society is closed* **then**
        if $(21 \leq Age \leq 55)$ **then**
            if *#kids is less than Maximum* **then**
                if *rand()* $\leq$ *reproduction chance* **then**
                    Create a new person with age = 0 and random parameters
                    Increase number of kids by 1
    Cheating cost = 0
    if *potential cheater* **then**
        /* Calculate provisioned income, based on Master's and Agent's capital */
        $t \leftarrow 1$, cap(0) ←My capital, $I(0) \leftarrow 0$, For commenda Mcap(0) = Master's capital and Mcap(0) = 0 for the rest.
        while $t \leq 6$ **do**
            $I(t) \leftarrow (aai + aais \times s) \times$ [0.3× Mcap $(t-1)$ + cap $(t-1)$]
            cap$(t) \leftarrow$ cap$(t-1) + I(t-1)$
            Mcap$(t) \leftarrow (aai + aais \times s) \times 0.7\times$ Mcap $(t-1)$
            $t \leftarrow t + 1$
        Discounted Income $(\alpha \times FI) \leftarrow \sum_{i=1}^{6} \alpha^i \times I(i)$
        Consider a random manipulation (RM), $CI = RM$ for commenda and $CI = G(< RM)$ for others.
        Learn pc, ppc, $ppnc$, and effectiveness of bond (eb).
        if $(pc+ppc)\times(CI-eb\times pc\times P)+(1-pc-ppnc)\times(CI+\alpha\times FI) > (1-ppnc)\times\alpha\times FI$ **then**
            Cheating cost = (RM)
    if *Commenda* **then**
        Master's capital ← $((Rand(aai) + Rand(irs) \times s) \times 0.7\times$ Mcap)− Cheating cost
    else
        Master's capital ← $((Rand(aai) + Rand(irs) \times s)\times$ Mcap) − Cheating cost

Algorithm 2 represents a brief overview of an agent in the society, (agent A). A gets 1 year older, and based on the mortality rate associated with his age dies with a probability and stops working if he is fired. In a closed system a fired agent continues his presence in the system but cannot trade any more. This assumption was inspired by Julfa institutions, i.e. the closed workforce instance that we have. We employ it to prevent a closed society artificially becoming extinct (line 1). A high mortality rate in an open society causes a part of the society to prefer leaving the company for a healthier life back home (line 2-3). The rest of the algorithm is applicable for working agents (line 4 indicates this concept). A's skill (s) linearly improves during the first ten years until he reaches his maximum attainable skill (line 5). In a closed system, A reproduces another agent (male kid) while he is aged between 21 to 55 with a probability until he either has maximum possible kids or dies (line 6-11). Each new born agent has totally new parameters, i.e. he won't inherit bad reputation, skill, or cheating tendency.

We recalculate the cheating costs incurred to the system by agents per run (line 12). A potential cheater decides whether to cheat or not based on the aforementioned game (line 13-24). To do so, first A calculates his provisioned *reward* based on the form of the contract and considered time horizon and cumulated capital in subsequent iterations. So, A considers no Income for now ($I(0)$) and the effects of master's capital in commenda contract (line 14). Then, the reward is calculated based on the assessed average income (aai) plus average attainable income for skill ($aais$) multiplied by the degree of skill (s) for the considered time horizon (lines 15-19). A considers the near future in this calculation, in our simulation (6 years). Then, A discounts provisioned income using his discount factor (line 20). Cheating is considered by assuming that it is a random manipulation (RM) with a linear correlation to its visibility. This randomness reflects intuitions about more manipulation is more visible and available opportunities for manipulating orders. In the commenda the trader would make as much as the profit that he hides from his master, because he is the one who buys and sells the items. In EIC the agent's profit at most can be that much, since most of the time it was in the form of accepting a gift from other parties to change the orders[3] (line 21). Afterwards, A updates his estimations of probabilities of reactions to his current state based on observations and his prior and the effectiveness of bonds for EIC (line 22). Consecutively, A decides either to cheat or not based on rewards, punishments, and other estimated parameters (line 23-24). Finally, A updates his capital as well as master's capital (line 25-28). Note that the master capital directly affects system profitability that is a function of payment scheme and cheating costs incurred by A and for commenda is 30% less due to the profit sharing.

Now we discuss parameters that were fixed in our simulation and reasons for choosing these numbers. The number of agents is defined based on the approximate society population. In Julfa around 800 traders (master and agents) were available at 17th century [2] and in EIC based on the number of factories[4] and their population, the number agents estimated as 500. So, we used 500 agents

[3] The most frequent reported cheats include embezzlement, making up Indian names to sell own items, accepting gift from brokers, i.e. choosing best gift giver or parties that work in private trades to increase bargain power for own benefits [15].

[4] For a list of these factories in India see [19], Map 2 (p.65).

for both societies. In systems with high mortality rate α, was calculated so that in 10 years it reaches 1% for low life expectancy. Moreover, in Julfa we used numbers based on reported customary interest rate ($\approx 10\% \rightarrow (1/1.1) \approx 90\%$) [12]. Each agent has a finite time horizon (6 years) for calculating his utility function. The mortality rates, their functions, and reproduction rates for the two societies are obtained from [2, 7, 10, 13].

Table 4: Simulation Parameters

Name	Description	Distribution	Value(s)
Discount Factor	Low Mortality Rate High Mortality Rate	Normal (μ, σ)	(0.9,0.033) (0.63, 0.12)
Years	Constant	6	
Revenue	Both local and Masters	Uniform	(0.05, 0.1)
Population	Mature population (Plus kids for closed system)	Constant	500
Potential cheater rate	Chance of being a potential cheater	Constant	0.5
Proportion to Fire	Fired per run for bad performance (no adjudication process)	Constant	0.004
Revenue Extent	Linear function of skill	Uniform	(0, 0.1)
Skill	Maximum attainable skill	Uniform	(0.5, 1)
Chance of Identifying Cheaters	By agents with direct link By masters in closed system By masters in open system, discounted by 1% for disloyalty	Uniform Beta Uniform	(0, 1) (1, 5) (0, 1)

Furthermore, based on the approximated ROR associated with EIC during 1710 - 1745, the average is 9.74[5]. In our model, we assume a minimum revenue can be made by trade that merchants cannot manipulate. Then, each agent starts with 100 units of money from master's capital, 10 units of money of his own capital for local trades. They have approximately 20 random connections with other agents that can observe and learn from. A new employee creates around 20 random connections to agents presented in the system; the connection is lost once a person leaves the society. Finally, the bonds are 50 units of money for agents with 1-5 years of experience, 100 for agents with 6-8 years of experience, and 150 for more experienced ones.

4 Simulation Results

In this section we discuss simulation results for 10 systems we considered. We used 30 different seeds for each system then averaged their results. Moreover, we assume each run reflects a year, and both systems used these institutions for around 150-200 years[6]. So, the number of runs in this simulation was bounded to 200 iterations. We gradually change attributes of EIC to get closer to Julfa to examine their effects. Based on these combinations we study the effectiveness of

[5] A detailed table is provided in [4], Table A.26 (p.440).
[6] EIC legalised local trades for agents in late 17th and early 18th AD and Julfans were active for less than 200 years.

these systems in identifying and firing cheaters, reducing the percentage of the cheaters, improving the skill of people, and making more profits. It is worth mentioning that we did not add punishment compensations when calculating income, because it makes it hard to identify the real reason for system's profitability. In Table 5 attributes of these societies are presented (because punishment is a function of having adjudication process plus the contract form, we did not include it in this table). Each societal configuration is denoted by a Roman number, e.g., I indicates a closed society facing high mortality rate without commenda and adjudication process.

Table 5: System Setups

Attributes	EIC	I	II	III	IV	V	VI	VII	VIII	Julfa
Commenda	✗	✗	✗	✗	✓	✗	✗	✓	✓	✓
Open	✓	✗	✗	✗	✗	✓	✓	✓	✓	✗
Adjudication	✗	✗	✗	✓	✗	✗	✓	✗	✓	✓
Mortality Rate	H	H	L	L	L	L	L	L	L	L

Now, we discuss the results of simulation runs which are indicated in Fig. 2. The x-axis of this figure represents number of years from system establishment and the y-axis indicates percentage of cheaters in society (for Fig. 2a-2f). Moreover, comparisons between EIC and Julfa (Fig. 2g) and two systems with unique behaviour (Fig. 2h) are represented for further discussion. The aforementioned figure (Fig. 2g-2h) includes the percentage of cheaters, fired cheaters, and total fired agents. As can be seen, there are fewer cheaters in systems run by commenda (Fig. 2a) than those with no commenda (Fig. 2b), that indicates impact of this profit sharing on agents behaviour. With or without adjudication (Fig. 2c-2d) does not decrease the number of cheaters except for VII. Moreover, as indicated in Fig. 2h it would create an increasing cheating trend in IV (which is like Julfa except with adjudication). Furthermore, closedness of workforce society (Fig. 2f) does not decrease the number of cheaters. This behaviour emerges as a result of random priors, but closedness of system helps identifying and firing cheaters (see Fig. 2g-2h). However, it should be emphasised that this number is cumulative, i.e. cheaters are remained in closed system. Openness of the system (Fig. 2e) is not the only reason for cheating. As indicated in Fig. 2h, openness has an impact on estimations about weak monitoring (i.e. almost all cheaters remained in next run) and gradually increases number of cheaters in VIII. The first peak in VIII is caused by experienced agents who started working for the system. They have limited capital (they had not accumulated any profit before), but they had enough skill and access to organisation's capital. So, these agents cheat until they gradually die. Finally, as can be seen in Fig. 2g, EIC has a big number of cheaters, and most of them are not identified; but in Julfa this number shows much lower and almost all cheaters are fired.

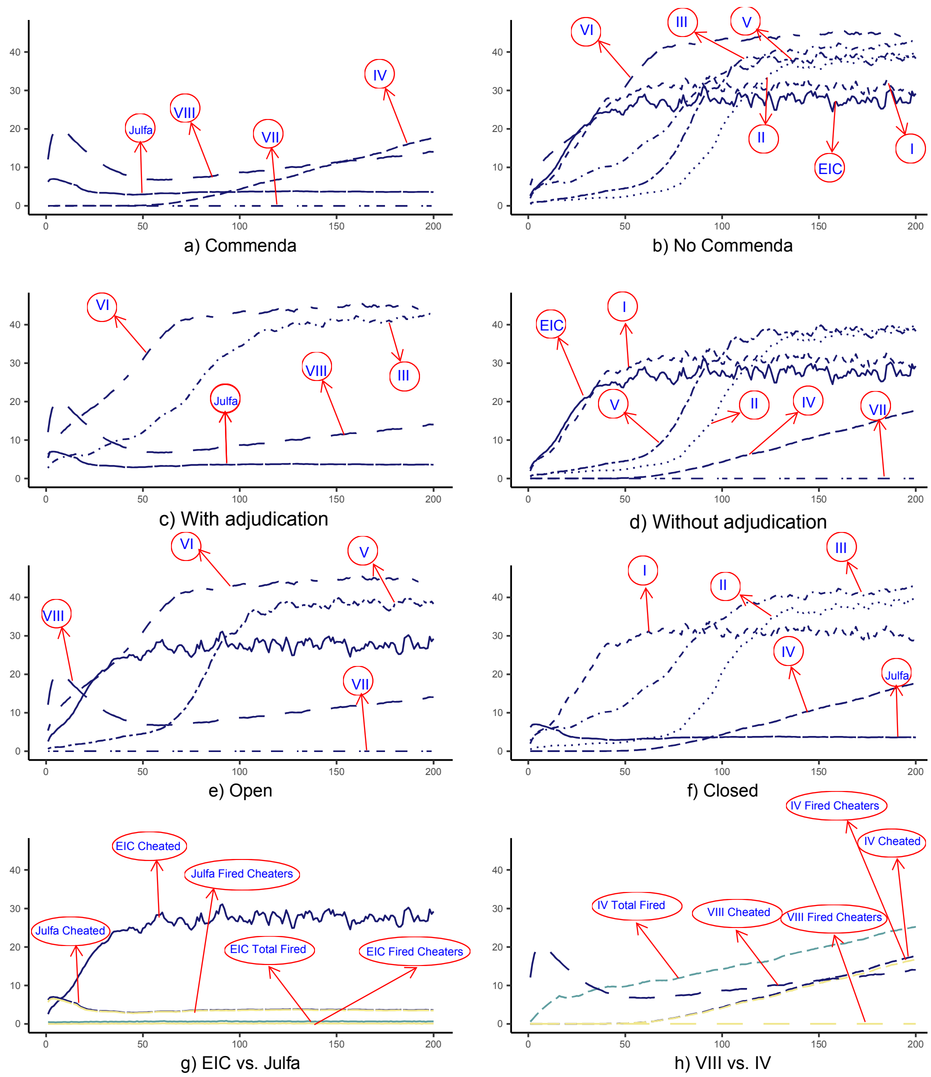


Fig. 2: Percentage of fired and cheater members of society, x-axis is number of years and y-axis is percentage of cheaters in society for (a-f). Percentage of cheaters, fired agents, and fired cheaters present for selected societies in (g-h).

The next step is to see if it is rational to share a substantial amount of profit with employees and assess the effect of different firing schemes on improving average skill of workforce and ROR in the system. In Fig. 3 sorted ROR (top) and the average skill (bottom) for different setups are presented. A closed system has a good effect for EIC by improving managers ROR. Moreover, from five best RORs four of them, i.e. Julfa, IV, VII, and VIII shared 30 percent of profit with agents. So, this sharing scheme pays itself back by deterring agents from cheating. On the other hand, a combination of closedness and low mortality rate (cases II, III, IV, and Julfa) can improve profitability. EIC policy, regardless of mortality rate is inferior so that of case V (i.e. low mortality rate counterpart of EIC) only outperforms case VI (i.e. no commenda with adjudication). So, in an open society with poor monitoring, having adjudication without a profit sharing scheme does not guarantee profitability of the system.

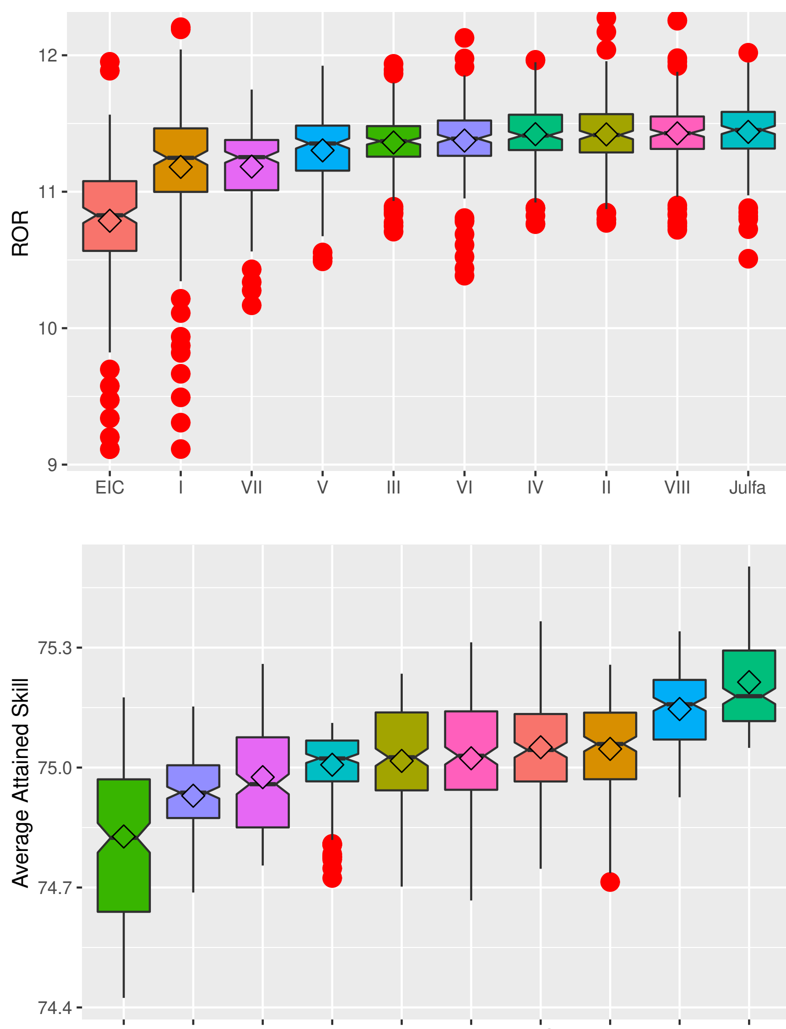


Fig. 3: ROR (top) and average skill (bottom) for different system settings.

Finally, the worst average skill is for III (see Fig. 3 bottom), wherein, the agents are paid low, cheated, and identified soon, and low-skilled agents remained as long as they did not cheat. The best level of skill is related to case IV, where people are judged based on their performance in a closed society and paid well. Overall, when company traders are judged based on their performance, the average skill in the system increases. However, most cases that have adjudication process (i.e. III, VI, and Julfa) faced a low level of skill. The only counter example is case VIII and the level of skill can be ascribed to a combination of commenda and openness, i.e. cheaters are present in the system and gain more skill. Finally, EIC was far better in improving skill of agents, especially if we consider its low mortality rate counterpart (V). Using the Wilcoxon Test we learn that there is not any significant difference among RORs of II, IV, VII, VIII, and Julfa (commenda payments and EIC with low mortality rate and closed workforce). These systems outperform other societies in profitability. Moreover, RORs of I, V, and VI do not indicate any significant difference (in an open workforce society adjudication process is not helpful). Average skill in IV and V (EIC with low mortality rate) dominates all other societies, and III shows the lowest skill level across all other societies. With these insights in mind, in the following section we discuss these results and their implications, before providing pointers towards future work.

5 Discussion

This study sheds some lights on what happened in two historical societies, namely EIC and Julfa. The simulation inspired by Greif's work [8] uses an incomplete information game aimed to investigate effects of some institutional attributes of EIC and Julfa. The results suggest that it is rational to share a significant amount of profit and then punish cheaters based on the revealed cheating. This scheme increases profitability of the system without other auxiliary means, i.e. adjudication process or monitoring. Moreover, a combination of no adjudication process and commenda may persuade agents to avoid cheating at first but in a closed society, remaining in society after getting fired would invert this effect after awhile. For case I (closed counterpart of EIC with the same mortality rate), to stabilise population we increased maximum number of agents from 1.4 to 10.4, i.e. around 21 kids with 70% probability of having a child per year. These numbers show why EIC could not afford to incorporate a closed system, especially if we consider the harshness of assumptions, i.e. having 21 kids in 30 years while agents are working in another continent. These figures emphasise the validity of our assumption about less mortality rate in Julfa. Finally, the most significant impact of closedness of the system was on the identification of cheaters, i.e. if a system is not designed well for punishments or rewards and we only monitor well, we eventually face a large number of cheaters in society, even though they may know they would be identified. A controversial result of this simulation is related to the situation of not having a court and adjudication chance improving system profitability under certain conditions. This outcome should be examined further using other learning parameters or methods.

The results of simulation indicate the effect of limited information about a system on agents decision making, as is suggested by the rational choice perspective, e.g. in case IV agents behaviour shows an increasing cheating trend due to the accumulation of fired people for bad performance. Another example of results that are predicted by the rational choice perspective is the impact of low payment schemes on agents cheating in order to make fast and easy money. On the other hand, the point that sharing profit and payments based on performance persuades agents to work better is a phenomenon observed in other studies [9]. Based on results of this simulation, payment should be a function of both access to company resources and performance. Otherwise, good monitoring, and not having adjudication process and punishment cannot control cheating behaviour. Moreover, in creating a closed collaborative society some simple parameters like environmental hazards and mortality rate have significant effects. Neglecting them introduces significant issues.

There are some limitations to our current work. This simulation neglected some psychological effects that are discussed in studies such as [1]. We assumed that there are the same chances to make profit by local trades. Relaxing this assumption may increase the cheating rates in society. Moreover, we did not consider certain aspects in this study such as mimicking other participants' behaviour, consequences of living in a system with a high proportion of cheaters, or punished cheaters. For future work, we will consider effects of informal apprenticeship and sharing information about opportunities in closed systems and the impact of payment on the loyalty of agents in an open system.

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