Institutions for Contract Enforcement and Risk-sharing: from Debt to Equity in Late Medieval Venice.

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Abstract

This paper integrates a historical institutional analysis of the emergence and transition of various contracts with the study of their efficiency attributes. In particular, it uses historical records and a context-specific mechanism-design model to investigate the institutional and contractual arrangements that facilitated mobilization of capital and risk-sharing in late medieval Venice. Institutional arrangements that enhanced the State's ability to verify information led the transition from the sea loan (a debt-like contract) to the commenda (an equity-like contract). This implied a better allocation of risk and, arguably, further mobilization of capital. This empirically supported explanation for the development of alternative contracts differs from both a simple "reputation mechanism"— according to which exchange is done through networks— and the standard static explanations of optimal security design— which focuses on the efficiency of various contractual forms ignoring their underlying institutional foundations. The paper also provides a rationale for the efficiency and observed co-existence of debt and equity, as well as for the participation of merchants-entrepreneurs to the funding of their own ventures (inside equity).

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1 Introduction

> I, Pietro Corner, ... have received from you ... 100 hyperpers, with which I ought to go on voyage to do business ..., and I ought to give and deliver to you 125 hyperpers. However, this credit ought to be at your risk from either sea or people, if this will be clearly apparent.
>
> I, Giovanni Corner, ... have received from you ... 50 Venetian silver pennies, with which I ought to go on voyage to do business with and trade ..., and I ought to give and deliver to you ... all your above mentioned capital with three quarters of all the profit the Lord will grant with a fair and true accounting, and I should retain to me one quarter of the profit. However, your aforementioned credit ought to be at your risk from either sea or people, if this will be clearly apparent. [Morozzo della Rocca and Lombardo, 1940, docs. 134 and 522]

On December 1158, a rich Venetian merchant, Pietro Corner, raised additional funds through a sea loan (a debt-like contract) to finance one of his trading ventures. Some 50 years later, on August 1210, the family's new generation used a better risk-sharing commenda (an equity-like contract). Both contracts entailed the financier to recoup only the amount saved from loss at sea or from the hostile action of people and each was representative of its own time period. Did the Venetians grow smarter or were they facing a changing environment? Since the commenda was known long before it was adopted and the sea loan persisted even late in the thirteenth century as the mean to fund those ventures which most resembled the trading conditions of the previous century, the evidence favors the latter view.

Standard contract theory has nicely introduced the concept of incentive-compatibility to explain the use of non-contingent/contingent contracts under various information structures [Townsend, 1982; see Marimon, 1991, for an application to these historical contracts]. Under hidden information, the merchant has incentives only to misreveal the actual profitability of his venture. Thus, in the absence of (verifiable) information, the merchant is unable to truthfully commit to repay a contingent amount, and mutually beneficial risk-sharing is foregone: by paying out a fixed amount in return for the capital received, Pietro bore all the commercial risk. Under full information, incentive-compatibility constraints are relaxed, because an almighty legal system can confiscate all the venture's profits at no cost if the merchant refuses to fulfill his contractual obligations: Giovanni was thus able to credibly commit to divide the commercial profit according to a ratio agreed upon and thus shared the commercial risk with his financier.

But, what kind of institutional environment supported these different information structures? Do we really observe institutional developments that enhanced the State ability to verify information? If so, did a shift in contractual relationships follow? Did the Venetians respond optimally, as theory assumes, to a changing institutional environment? What can Contract Theory tell us about the sharing of the "risk of sea and people"? After all, both the sea loan and the commenda were contingent contracts: in the case of loss at sea or from the action of enemies, they both exempted the merchant from repayment beyond the amount retrieved from misfortune, if the loss was "clearly apparent." Why did merchants contribute to the financing of their own ventures but resorted to outside funds before investing all their capital?

There is consensus among historians that the commenda was "a medieval innovation of the highest importance and contributed greatly to the fast growth of maritime trade" [Lopez 1976; p.76], which, in turn, led to both economic growth and fundamental political, social and economic changes [Greif, 1992; Lopez, 1976; North, 1991]. Venice, in particular, became the richest city of Europe during the late medieval period and the main European financial center for hundreds of years while enjoying political and social tranquillity [Lane, 1973]. However, the present historical and economic literatures neither adequately explain the intriguing transition from the sea loan to the commenda nor evaluate its efficiency implications.

Despite the logical link between the set of enforceable contracts and the institutions that support them, the institutional and contractual literatures have evolved along disjointed paths. The Historical Institutional Analysis aimed at exploring institutional developments that mitigated various commitment problems over history, has paid very little attention to observed contractual forms [see, among others, Greif, 1989, 1993, 1994, and 2000; Milgrom, North and Weingast, 1990; Greif, Milgrom and Weingast, 1994; Clay, 1997; and Moriguchi, 2000]. Quite the opposite, the Optimal Security Design literature has dealt with the efficiency of various contractual forms ignoring their underlying institutional foundations [see, among others, Townsend, 1979 and 1982; Gale and Hellwig, 1985; Lacker and Weinberg, 1989; Bolton and Scharfstein, 1990; Chang, 1992; Hart and Moore, 1998]. The New Institutional Economics has studied both institutional and contractual arrangements but these has been analyzed separately [North, 1990, and Williamson, 2000]. In particular, Transaction Cost Economics focuses on the governance of contractual relations holding the institutional environment constant. This paper, in contrast, emphasis the necessity of studying institutional and contractual changes in a combined manner.

The paper advances that in Late-medieval Venice institutional arrangements that enhanced the State's ability to verify information expanded the set of contracts that the Venetian State could enforce and enabled the transition from the sea loan (a debt-like contract) to the commenda (an equity-like contract). This implied a better allocation of risk and, arguably, further mobilization of capital. The paper also shows that the sea loan and the commenda contracts sustained the optimal allocation of risk given their underlying institutional foundations. Moreover, the enhanced State's ability to verify information supported the first-best allocation of risk, which was attained by letting the merchant finance part of the venture and raising additional funds through commenda contracts. Thus, the paper provides a rationale for the efficiency and observed co-existence of debt and equity, as well as for the participation of merchants-entrepreneurs to the funding of their own ventures (inside equity).

To substantiate these theses, I have developed a theoretical model and confronted its assumptions and predictions with empirical evidence from almost 1000 notarial acts (found in the Archivio di Stato of Venice and transcribed in full by Morozzo della Rocca and Lombardo [1940 and 1953]).

The model is in the tradition of modern corporate finance, which allows for optimal security design. It is closest to the costly state verification/falsification literature (Townsend, 1979; and Gale and Hellwing, 1985/ Lacker and Weinberg, 1989), which, in a one-period comprehensive contracting framework, derives the optimal income rights of debt (the sea loan) or equity (the commenda). However, it differs in its main assumptions— and results— to capture the details of the historical episode. In my model, all agents are risk-averse, each might be endowed with the resources required to finance the venture by his own, there are both a navigation and a commercial risk, and there is no verification/falsification cost to be minimized. Instead, contracts are designed to provide the optimal allocation of risk, given the State's ability to verify information at infinite or zero private cost.[1] In particular, the observed institutional arrangements that provided the verifiable information required for the existing State to evaluate merchants' conduct and punish cheaters are captured by a parameter that changes the information structure, leading from hidden information to full information in the model.

The model then predicts the (second-best) use of the sea loan when and where verifiability constraints are binding and the (first-best) use of the commenda when these constraints are relaxed. I then identify empirically various situations in which the State could not verify the true venture return and others in which the State could, and find that the sea loan and the commenda were used as predicted. Thus, debt (the sea loan) and equity (the commenda)

[1]In contrast to the Costly State-Verification literature, the threat of verification is credible because the financier does not need to incur any verification cost. The resulting absence of ex-post inefficiencies makes debt optimal even if stochastic verification-bankruptcy schemes, like auditing, are allowed. Also, the optimality of debt and equity are robust to the allocation of bargaining power.

can coexist under various information structures. Also, the transition from the sea loan to the commenda can be accounted for as reflecting changes in the State's ability to verify information. Further, the model predicts the observed fact that the merchant invest only part of his wealth in the trading venture he managed. This result is novel in the optimal security design literature, both in the costly state-verification literature and in the incomplete contracting one.

The model is also related to the optimal security design literature with incomplete contracting in which the financier needs to induce the merchant to reveal the return truthfully because he cannot force him pay out, at any cost [Townsend, 1982; Bolton and Scharfstein, 1990; Hart and Moore, 1998]. Like my model under the hidden information structure, these papers assume that commercial returns are non verifiable and hence are noncontractible. Unlike my model, long-term contracts enhance financial contracting. In a one-period model, incentive compatibility (verification constraints) prevents contingent exchanges that are mutually beneficial when information is complete. First-best commenda contracts cannot thus be enforced in my model, which delivers a sea loan contract with no commercial risk-sharing. In a simple two-period model, however, agents can circumvent the incentive information difficulties of single-period agreements by making future exchange contingent on present claims.

Despite the potential gain from enduring relationships, sea loan contracts were one-shot agreements.[2] In the context of repeated games with imperfect monitoring, however, short-term formal contracts like the sea loan can facilitate the implementation of a long-term implicit contract, under which the financier threatens the merchant to stop exchanging in the future if he discover that the merchant has ever cheated. Yet, the evidence indicates that in late-medieval Venice such reputation mechanisms did not govern financial relations. On the contrary, the State functioned as an enforcement and information-transmission mechanism [González de Lara, 2001].

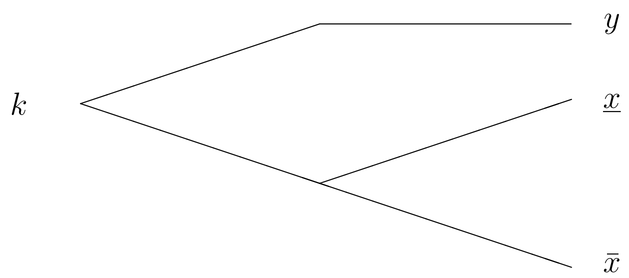
The organization of the paper is as follows. Section 2 models the contracting problem faced by merchants and their potencial financiers, and provides a full characterization of the (constrained) efficient financial structure (all the proofs are in the appendix). Section 3 evaluates empirically both the assumptions and the predictions of the theoretical model. Finally, section 4 concludes and sets an agenda for future research.

[2]Moreover, one should bear in mind that although the sea loan and the commenda were characterized by the very same income rights of today's standard debt and equity contracts, they were silent about the allocation of control rights, which are at the heart of the incomplete contracting literature.

A tentative explanation for the absence of Pareto-improving formal long-term contracts is developed in the companion piece of this paper, Gonzalez de Lara [2001].

2 The Model

Consider a one-period two-dates contracting economy with a merchant and a financier who face the possibility to undertake a single welfare-enhancing trading venture. Both agents are risk averse with preferences represented by continuous and twice-differentiable utility functions $U^i(c^i)$, exhibiting a decreasing absolute risk aversion (DARA) coefficient with $U^{i'}(.) > 0$, $U^{i''}(.) < 0$, where c denotes consumption and the suprascript $i = 1, 2$ stands for the merchant and the financier, respectively.[3] Each agent i is initially endowed with k^i units of good and maximizes his expected utility from second-date consumption. Goods can be costlessly self-stored or invested in the trading venture. Any amount of the good can be stored but the investment is lumpy. The venture requires k units of investment, plus the participation of the merchant. It yields a random return $s \in S = \{y, \underline{x}, \bar{x}\}$ with probability p_s, where y denotes the loss due to the navigation risk and $\{\underline{x}, \bar{x}\}$ stand for the risky commercial return, with $0 \leq y \ll k \ll \underline{x} < \bar{x}$. The navigation risk refers to the so-called "risk of sea and people" and included the risk of natural shipwreck, piracy and confiscation of property by foreign rulers. The commercial risk accounted for wide variations in profits depending on the tariffs and bribes paid in customs, transportation and storage fees, the conditions of the goods upon arrival after hazardous trips, the amount pilfered by the crew while loading and unloading, fluctuations in prices, and so on and so forth.



To account for the optimality of undertaking the trading venture, we assume that

$$E[U^i(s)] > U^i(k) \; \forall i, \tag{1}$$

which in combination with DARA preferences ensures that the higher productivity of the trading venture ($E[s] > k$) compensates for its risk. Therefore, agents will only self-store and consume their autarkic endowments, k^i, as a reflection of their inability to mobilize funds in long-distance trade. For ease of notation, let $w_s = k^1 + k^2 - k + s$ be the second-date total risky endowment of the economy when the venture is undertaken. We first study the

[3]Note that Innada conditions are not assumed to hold, so that we do not force and interior solution.

case in which the merchant is constrained to rely on external funds because of a shortage of his owns and, for simplicity, he is assumed to have zero initial wealth, $k^1 = 0$. Then, the model is extended to capture the situation in which the merchant can finance the venture entirely on his own, $k^1 > k$. The financier is always endowed with enough resources to fund the venture, $k^2 > k$.

At the first date, when investment decisions are taken, there is no information whatsoever on the true realization of the venture return. At the second date the return is realized and revealed to the merchant. We assume that the existing Venetian State could always observe and verify the realization of the navigation risk, and consider two extreme scenarios regarding the ability of the State to evaluate the true commercial return. Under the hidden information structure ($\theta = 0$) neither the financier nor the State can distinguish between the commercial returns, at any cost. However, the State can force the merchant pay out the minimum commercial return, $\underline{x}$, which is verifiable. Under the full information structure ($\theta = 1$) the State can verify the true return without any private cost for the financier.

Before proceeding, several comments are in order. First, the model characterize the non-diversifiable risk associated with trading ventures (there is only one investment project).[4] From the eleventh to the thirteenth centuries risk could not be diversified or insured at the aggregate level because *(i)* trading ventures were subject to significant indivisibilities and capital was scarce, so that only a few could be financed and *(ii)* those actually financed entailed an aggregate risk. Indivisibilities took the form of both start-up costs, such as manning and outfitting a ship, and optimal size requirements, given by the cargo capacity of each ship and the minimum amount of capital required to generate the expected profit necessary to compensate merchants for taking the risks and inconvenience to set sail and trade.

The aggregate risk derived from the "risk of sea and people" not being independently distributed among merchants' ventures. Firstly, those merchants voyaging on the same ship faced the very same navigation risk. "A typical cargo probably represented the stakes of something like a hundred investors who had confided sums of various amounts to more than a dozen traveling merchants" [Lane, 1973, p.52]. Secondly, while voyaging on convoy provided protection from pirates, it presented a concentrated target. If the convoy were captured, the loss would affect a significant part of *all* the Venetian merchants. For example, in 1264 the Genoese, at war with the Venetians, lured away the escorting galleys of the yearly convoy

[4]As a result, the model does not reveal diversification although, in reality, each trading venture entailed an idiosyncratic risk that could and actually was diversified to some extent.

to the crusaders' states and caught the unprotected Venetian convoy at sea. Although the Venetians defied the Genoese by withdrawing to the very large round ship on the convoy, the smaller vessels and the bulk of their cargos were lost, as well as a whole year's trade with Cyprus, Palestine, Syria and Egypt. Thirdly, the most productive trade exposed the bulk of the Venetian merchants to the political mood of only a few Eastern rulers. For example, when the Byzantine Emperor Manuel Comnenus ordered the arrest of the Venetians and the seizure of their property on March 1171, the Venetians suffered immense losses. Venetian merchants in the Byzantine territory at the time of confiscation have been estimated to sum up to 20,000 (over a total population of less than 100,000) and there is evidence of both mass imprisonment and devastating material losses [Ravegnani, 1991, pp. 52-56].

Second, the limited ability to diversify prevented both merchants and their potential financiers from effectively becoming risk neutral.

Third, the model implicitly assumes that the State could enforce contracts contingent on verifiable information. The Venetian State indeed did not only developed an effective legal system but it also generated incentives for merchants to submit themselves to its coercive power. Such incentives enabled merchants to commit not to embezzle capital and never return to Venice, above and beyond the boundaries of the court's jurisdictional power and the limited ability of a medieval court to exercise its coercive power over a merchant who emigrated.[5]

Fourth, there are empirical grounds to assume that the State could verify whether the merchandise was lost due to the navigation risk. To help verify whether such losses had actually been incurred or not, merchants during the twelfth century were required to voyage on well-identified ships and trade in pre-determined ports, and they were forbidden to change these terms, except by the explicit agreement of the majority of the merchants and the crew. Although merchants who joined the state's fleets during the thirteenth century were free to voyage on any ship on the convoy and trade in any of the markets at which the convoy called, they were nonetheless monitored by the ship scribes and other government officials, both on board and in the Venetian colonies where the convoys stopped. All vessels returning from the

[5]The companion piece of this paper [González de Lara, 2001] substantiates this assumption and, in particular, shows that the State developed various institutional arrangements that created and sustained economic rents to which only Venetians had access, hence rewarding merchants who kept their affiliation with Venice and generating effective barriers to exit. These economic rents derived mainly from very unique commercial privileges that secured Venetian property rights abroad, reduced the punitive custom duties they must have paid otherwise, provided attractive lodgings and warehouses facilities, and so on and so forth. To sustain the commercial rents, the Venetians established barriers to entry, which excluded foreigners from Venetian markets for overseas trade. Immigrants were thus required to reside and pay taxes for twenty-five years before acquiring full rights of citizenship.

Levant were ordered to stop in Modon and Coron, "the two eyes of the Republic," to have news and give news of maritime and commercial events [Lane, 1973, p. 43].[6] Finally, the model includes a parameter θ that captures the provision of verifiable information regarding the commercial return, as described in section 3.1.

2.1 Contracts

We consider allocation that can be obtained by means of a *contract* enabling the funding of the venture and specifying transfers from the merchant to the financier both at the first and at the second date. First-date transfers $\tau \in \Re$ are prior to the realization of the state and, accordingly, are independent of it. Second-date transfers τ_s are contingent on the state, where $(\tau_y, \tau_{\underline{x}}, \tau_{\bar{x}})' \in \Re^3$. A contract will result in *consumption schedules* for the merchant and the financier, c^1 and c^2 respectively, where $c^1 := c^1_s = k^1 - k + s - [\tau + \tau_s]$ and $c^2 := c^2_s = k^2 + [\tau + \tau_s]$.

Historically, financial relations were established through debt-like sea loan and equity-like commenda contracts. Even when merchants were endowed with the resources required to fund their ventures on their own, they preferred to only finance part of it— ϕk, with $\phi \in (0, 1)$— and raise the remaining capital— $\tau = -(1-\phi)k$— through sea loan or commenda contracts. In return for funds, the financier received a contingent claim on the venture return. Both the sea loan and the commenda established repayment equal to all what was saved from misfortune on the event of loss due to the navigation risk. Thus, merchants were partially insured against the navigation risk, for they were exempted from repayment beyond the amount retrieved from a navigation incident— $\tau_y = y < k$. However, they did not enjoy full insurance, which would have required a coverage payment— $\tau_y < 0$ instead of $\tau_y = y \geq 0$— to offset the merchant's lack of gain in that event. These contractual arrangements differed only in the transfers they established in the case the ship arrived safe and sound in port. Whereas the sea loan paid out a fixed constant, the commenda divided the commercial profit according to a ratio agreed upon, and thus shared, not only the navigation risk, but also the commercial risk between the merchant and his financier.

Definition 1 *A sea loan contract establishes* $-k \leq \tau < 0$ *and* $\tau_y = y < \tau_{\underline{x}} = \tau_{\bar{x}}$.

Definition 2 *A commenda contract establishes* $-k \leq \tau < 0$ *and* $\tau_y = y < \tau_{\underline{x}} < \tau_{\bar{x}}$.

[6] For a further elaboration on the verifiable character of the navigation risk, see González de Lara [2001].

But, if the sea loan sustained a worse risk allocation than the commenda (risk averse merchants bore all the commercial risk), why was it used? Standard contract theory informs us that contingent commenda contracts are non incentive-compatible under hidden information. Fixed-repayment sea loan contracts emerge thus in the model because of the merchant's inability to commit to truthfully reveal the commercial return ($\theta = 0$), and are replaced with better risk-sharing commenda contracts only when institutional arrangements alleviates this information problem ($\theta = 1$).

Yet, many questions should be addressed. Can we really identify changes in the selection of contracts in response to changes in the State's ability to verify information? And if so, why did the Venetians used the sea loan and the commenda rather than other contractual forms? In particular, why were the financier entailed to recoup all the capital saved from misfortune in case of navigation loss? Why did merchant finance part of the venture and raise additional funds through sea loan and commenda contracts before investing 100 percent of their own resources ($\phi \in (0, 1)$? Did the observed capital structure provide the optimal allocation of risk? The formal model provides the foundations for addressing these questions.

2.2 Optimal Contracts

A contract $(\tau, \tau_y, \tau_{\underline{x}}, \tau_{\bar{x}})$ is optimal if and only if it sustains an optimal allocation of consumption, which is defined as the solution to the following (concave) problem for some given value of $\overline{U}^2$. Further, we restrict our attention to contractual forms that sustain the optimal allocations for *all* individually rational levels of $\overline{U}^2$. Therefore— and in contrast with Lacker and Weinberg [1989], Bolton and Schartfstein [1990] and Hart and Moore [1998]—, optimal contractual forms are robust to the allocation of bargaining power and can thus explain the variety of financial relations that we observe: rich and powerful merchants from the ruling class who get funds from medium-class artisans are as common as non-noble merchants of low means who get funds from the leading aristocracy.

Problem 1: Choose event-contingent consumption allocations $\{c_s^i\}_{s \in S}^{i=1,2}$ to maximize $E[U^1(c_s^1)]$ subject to

$$E[U^2(c_s^2)] \geq \overline{U}^2 \tag{2}$$

$$c_s^i \geq 0 \; \forall i, \forall s \tag{3}$$

$$\sum_i c_s^i \leq w_s \; \forall s. \tag{4}$$

Restrictions (3)-(4) are feasibility constrains. Consumption cannot be negative and cannot exceed total resources. Constrain (4) holds with equality, since resources are not spared optimally. Therefore, $c_s^1 = w_s - c_s^2$ and the problem can be solve on c_s^2 for $s \in S$. It also follows that (2) holds with equality, so that the concave utility possibilities frontier can be traced out as the parameter $\overline{U}^2$ is varied. Individual rationality imposes both a lower and upper bound on $\overline{U}^2$. Hereafter, this parameter is restricted to lie in this interval.

The lower bound $\overline{U}^2 \geq U^2(k^2)$ is given by the financier's ex-ante participation constraint, which ensures that he is as well off under the contract as he is under autarky. The upper bound of the parameter $\overline{U}^2$ varies depending on the merchant's initial endowments. If he is endowed with zero wealth, $k^1 = 0$, then $\overline{U}^2 \leq E[U^2(k^2 - k + s)]$ because the merchant would always be willing to undertake the venture. His ex-ante participation constraint, $E[U^1(c_s^1)] \geq E[U^1(k^1)]$, can thus be ignored, for his best alternative is consuming nothing in all the states, which gives him less (or equal) utility than he can get through contracting, as constraint (3) reads. If, on the contrary, the merchant is initially endowed with the necessary resources to finance the venture himself, $k^1 > k$, he can undertake the venture alone and consume $c_s^1 = k^1 - k + s$. In this case, his individually rational constraint

$$E[U^1(c_s^1)] \geq E[U^1(k^1 - k + s)] \tag{5}$$

is more restrictive than his ex-ante participation constraint, because of (1) for $i = 1$ and utility functions exhibit decreasing absolute risk aversion (DARA). This implies a smaller upper bound on the parameter $\overline{U}^2$ for $k^1 > k$ than for $k^1 = 0$.

Also, the restricted set over which contracts are optimally chosen changes depending on the assumed information structure. First, incentive-compatibility restriction (6) must be fulfilled when the merchant posses hidden information ($\theta = 0$), but it is relaxed when the commercial return is verifiable ($\theta = 1$). Second, hidden information restricts the upper bound of the parameter $\overline{U}^2$ to the expected value of the verifiable second-date endowment.

2.2.1 Optimal risk-sharing with $k^1 = 0$ and $\theta = 0$. The sea loan

Let us first examine the case in which the merchant is constrained to rely on external funds because of a shortage of his own ($k^1 = 0$) and has hidden information about the realization of the venture's return ($\theta = 0$). Incentive compatibility (see Townsend, 1982) imposes fixed consumption for the financier on the event that the ship with its cargo arrived at port safe and sound:

$$c_x^2 = c_{\underline{x}}^2 = c_{\overline{x}}^2. \tag{6}$$

Thus, hidden information naturally explains fix repayment in sea loan contracts ($\tau_x = \tau_{\underline{x}} = \tau_{\bar{x}}$). Yet, an explanation of the optimality of the sea loan needs also to account for its repayment in case of a navigation accident equal to all the capital retrieved ($\tau_y = y$).

Imposing restriction (6) under hidden information, the programming problem becomes

Program 2:

$$\max_{\{c_y^2, c_x^2\}} \quad E[U^1(w_s - c_s^2)]$$

$$\text{s.t.} \quad E[U^2(c_s^2)] = \overline{U}^2 \tag{7}$$

$$c_y^2 \leq w_y, \;\; c_x^2 \leq w_{\underline{x}}, \;\; c_s^2 \geq 0, \tag{8}$$

where $\overline{U}^2$ defines each individually-rational optimal allocation, with

$$U^2(k^2) \leq \overline{U}^2 \leq p_y\, U^2(k^2 - k + y) + (p_{\underline{x}} + p_{\bar{x}})\, U^2(k^2 - k + \underline{x}) < E[U^2(k^2 - k + s)], \text{ and}$$

restriction (8) combines the feasibility constraints (3) and (4) with the information constraint (6).

Graphical analysis

Let us depict the optimal event-contingent allocations of consumption in an Edgeworth Box, whose dimensions are given by the total resources of the economy in each state, $w_s = k^2 - k + s$. When $\theta = 0$, incentive compatibility imposes $c_{\underline{x}}^2 = c_{\bar{x}}^2 = c_x^2$. Therefore, there are two instead of three independent variables and the analysis can be drawn in a two dimensional picture, with a trick: the consumption of the financier is two event-contingent, but the consumption of the merchant is three state-contingent. Thus, figure 1 presents an Edgeworth Box in which the consumption of the merchant has two different origins. The presence of hidden information, and restriction $c_x^2 \leq w_{\underline{x}}$ in particular, also accounts for the shaded noncontractible area. This means that $c_{\bar{x}}^1 \geq \bar{x} - \underline{x} > 0$ because the merchant can expropriate ex-post the non-verifiable component of the profit, so that contracts with $\tau_x > \underline{x}$ are non enforceable and the maximum utility that the financier can achieve is given by $\overline{U}^2 \leq p_y\, U^2(k^2 - k + y) + (p_{\underline{x}} + p_{\bar{x}})U^2(k^2 - k + \underline{x}) < E[U^2(k^2 - k + s)]$.

[Figure 1 around here]

From figure 1 it is clear without further analysis that risk-free debt contracts providing constant consumption to the financier does not satisfy the financier's ex-ante participation constraint— PC^2 in figure 1— as long as the venture involves risk: $y < k$. In other words, risk-free loans sustaining individually-rational allocations, $c_x^2 = c_y^2 \geq k^2$, are not feasible (they lie outside the Edgeworth Box) because the merchant is short of resources to pay out a non-contingent transfer $\tau_y = \tau_x \geq k$ on the event of navigation loss. Therefore, the mobilization of capital in long-distance trade required the sharing of the navigation risk between the merchant an his financier. How much insurance would the financier optimally provide to the merchant?

Risk preferences

Let imagine for a moment a large number of independent and identically distributed ventures and merchants. If long-distance trade had been so characterized, the financier could have diversified the idiosyncratic risks faced by each poor merchant ($k^1 = 0$). Therefore, it would have been optimal for the financier to provide full navigation insurance— with $\tau_y < 0 \leq y$— to each merchant, whose consumption would have thus been smoothed.[7] In other words, on the margin the financier would have behaved as if he were risk neutral (each merchant being risk averse) and the sea loan— with $\tau_y = y$— would have not been optimal, Alternatively, if the merchant were risk-neutral and the financier risk-averse, the sea loan would be optimal and it would also be so if both agents were risk-neutral, since then any division of risk would be optimal.

[Figure 2 around here]

Let us now consider the most realistic case in which both the merchant and his financier are risk averse. Figure 2 illustrates different possible contract curves: CC' and CC. For parameter values leading to CC', the sea loan is not optimal: to sustain any allocation in the core,[8] the financier needs to provide more navigation insurance than the merchant enjoys through a sea loan contract: $c_y^2 < w_y = k^2 - k + y$. On the contrary, the sea loan is optimal for parameter values leading to a contract curve like CC in figure 1 and 2. The contract curve CC is such that at the corner point (c_y^2, c_x^2), with $c_y^2 = k^2 - k + y$ and $c_x^2 \geq k^2 - k + t^{pc}$, the slope of the merchant's indifference curve is smaller than the slope of the financier's indifference curve, meaning that, to renounce to a marginal unit of c_y^2, the financier wants more units of c_x^2 than the merchant values that extra marginal unit of consumption c_y^1. A corner sea loan contract establishing $\tau = -k$, $\tau_y = y$, and $\tau_{\underline{x}} = \tau_{\bar{x}} = \tilde{t_x}$ will then sustain the unique optimal

[7]Yet, merchants would have borne the commercial risk, because of hidden information. Therefore, the merchant's consumption would have not been constant across states: $c_{\underline{x}}^1 = w_{\underline{x}} - c_x^2 < w_x - c_x^2 = c_x^1 = c_y^1 = w_y - c_y^2 < w_{\bar{x}} - c_x^2 = c_{\bar{x}}^1$. The first and the last equalities derive from the incentive-compatibility constraint (6) and the inequalities from $w_y < w_{\underline{x}} < w_x < w_{\bar{x}}$, with w_x and c_x^1 defined such that $\frac{p_{\bar{x}}}{p_{\underline{x}}+p_{\bar{x}}} U^{1'}(w_{\bar{x}} - c_x^2) + \frac{p_{\underline{x}}}{p_{\underline{x}}+p_{\bar{x}}} U^{1'}(w_{\underline{x}} - c_x^2) = U^{1'}(w_x - c_x^2)$ and $c_x^1 = w_x - c_x^2$. Then, the first order conditions for a risk neutral financier can be expressed as $U^{1'}(w_x - c_x^2) = U^{1'}(w_y - c_y^2)$. This implies an optimal allocation such that $c_x^1 = c_y^1$.

[8]The core in this simple two-agent economy is standardly defined as the optimal individually-rational event-contingent consumption allocations. It is represented as the Pareto set that lies between the indifference curves that pass through the initial endowments, meaning the shaded interval of the Contract Curve CC' or CC in figure 2.

allocation of risk, with $\tilde{t_x} \in [t^{pc}, \underline{x}]$ taking different values for each individually-rational level of bargaining power $\overline{U}^2$.

In sum, because of the merchant's lack of resources, $k^1 = 0$, the financier needs to fund the venture in its entirety ($\phi = 0$ so that $\tau = -k$) and bears at least the navigation risk of losing the capital he contributes minus the amount saved from a navigation accident (feasibility constraints impose $\tau_y \leq y$). Under parameter values leading to CC, this transfer is optimally set at its bound, $\tau_y = y$, whereas for parameter values leading to CC', it optimally takes smaller values, $\tau_y < y$. The point is that contracting through sea loan contracts— with $\tau_y = y$— is not unambiguously efficient under two-side risk aversion. Under what conditions/parmeter values, if any, is the sea loan optimal?

Comparative Statics

A simple exercise in comparative statics leads to proposition 1, whose rationale is explained below and proved in appendix A.

Proposition 1 *The more risky and costly the venture is (the higher p_y and the lower y, the higher k relative to k^2, and the lower $E[x] = p_{\underline{x}}\ \underline{x} + p_{\bar{x}}\ \bar{x}$ given $\underline{x} \geq t^{pc}$), the more likely it is that the risk averse merchant raises funds from the risk averse financier through a sea loan contract, optimally.*

On the likely event of a navigation incident (p_y high), the financier could not recoup any amount beyond what was saved from misfortune, which was dreadfully insufficient (y very low) to reward the capital investment: $\tau_y \leq y \ll k$. This implied a very significant loss to the financier, for he invested a major part of his scarce initial endowment in the venture (k high relative to k^2). To compensate for the loss due to the navigation risk, the financier required soaring payments when the merchandise arrived at port safe and sound. This payment was very high relative to the expected value of the commercial return ($E[x] = p_{\underline{x}}\ \underline{x} + p_{\bar{x}}\ \bar{x}$ low, implying a low $p = \frac{p_{\bar{x}}}{p_{\underline{x}} + p_{\bar{x}}}$, $\underline{x}$, and/or $\bar{x}$). Sea loan contracts usually charged yearly interest rates above 33 percent for relatively safe ventures. For particularly risky voyages, like the return trip Romano Mairano undertook in 1167 from Constantinople to Alexandria, interest rates rose up to 50 percent, not yearly but for the duration of the voyage, which in this case lasted for no more than six months [see González de Lara, 2001].[9]

Therefore, voluntary financial contracting (the financier's ex-ante participation constraint) called for commercial transfers $\tau_x = t_x \geq t^{pc}$ such that the merchant consumed very little in

[9] Likewise, commenda contracts—which provided exactly the same navigation insurance than the sea loan, $\tau_y = y$— customarily remunerate capital with three fourths of the commercial profit.

all the states: $0 \leq y - \tau_y = c_y^1 < E[c_x^1] = E[x] - t_x \leq E[x] - t^{pc}$ with t_x decreasing as $\tau_y \leq y$ approximates y (PC^2 has a negative slope). On the contrary, the financier's event-consumption varied widely: $c_y^2 = k^2 - k + \tau_y \leq k^2 - k + y$ was very low while $c_x^2 = k^2 - k + t_x \geq k^2 - k + t^{pc}$ was very high. Thus, along PC^2 in the Edgeworth Box, the merchant's consumption was smoother than the financier's consumption

$$\max\{E[c_x^1] - c_y^1\} = E[x] - t^{pc} \ll t^{pc} - y = \min\{c_x^2 - c_y^2\}, \tag{9}$$

where the maximum (minimum) dispersion of consumption is achieved by setting $\tau_y = y$ and $\tau_x = t^{pc}$. Consequently, the equally risk averse financier valued consumption in the navigation event relatively more than the merchant and it was optimal that the merchant provided as much navigation insurance to the financier as possible, $\tau_y = y$. So, the sea loan emerged optimally for a robust set of parameter values like those stated in proposition 1.

Inequality (9) is thus a necessary and sufficient condition under two-side risk aversion for the optimality of the sea loan. The lower $E[x]$, the higher t^{pc}, and the lower y, the more likely (9) will hold, which happens to be the more risky and costly the venture is. First, the higher p_y and the lower y, the higher t^{pc}. Second, the more costly the venture (the lower $k^2 - k$), the more absolute risk averse the financier is and the higher the transfer t^{pc} he would required to compensate the navigation loss— because of DARA, the financier's indifference curves become more sloppy. Third, a decrease in y and $E[x]$ reduces the dimensions of the Edgeworth Box and shifts the merchant's indifference curves towards its flatter region (the origin of the merchant's consumption shifts to the south or to the west for smaller values of the parameters y and $E[x]$, respectively). It is worth noting, however, that $E[x]$ cannot take extremely low values because the verifiable return $\underline{x}$ needs to be high enough to enable a transfer $\tau_x = \tilde{t_x} \geq t^{pc}$ that induces the financier to fund the venture even though he only receive $\tau_y = y$.

As predicted, sea loan (and commenda, see next section) contracts with repayment equal to all the capital saved from a navigation incident, $\tau_y = y$, prevailed during the twelfth and thirteenth centuries, when trading ventures were indeed highly risky and costly. Also consistent with the model's predictions, the sea loan (and the commenda) lost their popularity when "commerce lost much of its adventurous and almost heroic features" (p_y lower and y higher) and "tended to become a routine" ($E[x] = p_{\underline{x}}\, \underline{x} + p_{\bar{x}}\, \bar{x}$ higher), and wealth accumulation due to trade reduced capital shortage (k^2 higher, at least with respect to k).[10] From late in the fourteenth century, insurance began slowly to develop as an independent form of

[10]The quotations are from the great historian of the Commercial Revolution Lopez [1976, p. 97].

business, providing merchants more insurance against the navigation risk than they used to receive through sea loan and commenda contracts. The new parameter values violated (9), leading to a contract curve such as CC' in figure 2 and a new optimal contractual form with $\tau_y < 0 \leq y$.

2.2.2 Optimal risk-sharing with $k^1 = 0$ and $\theta = 1$. The commenda

The previous subsection shows that the sea loan is the optimal contract for highly risky and costly ventures under hidden information ($\theta = 0$). Because the merchant is unable to commit to reveal a commercial return other than the minimum verifiable ($\underline{x}$ by assumption), he is constrained to undertake all the commercial risk ($\tau_{\underline{x}} = \tau_{\bar{x}}$) which is undesirable because both agents are risk-averse.

The provision of verifiable information ($\theta = 1$) relaxes incentive-compatibility constraints and enables Pareto superior commenda contracts, which share both the navigation and the commercial risks between the merchant and his financier: $y \leq \tau_y < \tau_{\underline{x}} < \tau_{\bar{x}}$. The optimality of the commenda, with $\tau_y = y$, over the expanded set of enforceable contracts ($\theta = 1$) can be derived from the optimality of the sea loan over the restricted set ($\theta = 0$), and hence the use of the commenda can be linked to the venture's risk and cost.

Under hidden information ($\theta = 0$), the financier optimally bear as little navigation risk as possible ($\tau_y = y$) while taking none of the commercial risk ($\tau_{\underline{x}} = \tau_{\bar{x}}$). Under full information ($\theta = 1$), the financier optimally undertakes part of the commercial risk ($\tau_{\underline{x}} < \tau_{\bar{x}}$), so that we might expect him not to bear also more navigation risk. Proposition 2, which is proven in Appendix B follows.

Proposition 2 *If the sea loan sustains all the optimal individually-rational allocations under hidden information* ($\theta = 0$)*, the commenda supports the corresponding allocations under full information* ($\theta = 1$)*. Thus, changes in the State's ability to verify information* ($\theta = 0 \rightarrow \theta = 1$) *leads to the selection of alternative contracts and enables a better allocation of risk.*

Moreover, this better risk-sharing opportunity leads to further mobilization of capital. In particular, it enables the funding of productive but commercially risky ventures that would not be financed under hidden information, because the minimum verifiable return is insufficient to compensate the financier: $\underline{x} < t^{pc}$. Under full information, the transfer in the better commercial state can be such that $\bar{x} > \tau_{\bar{x}} > t^{pc} > \underline{x}$ and thus compensate for a relatively low transfer $\tau_{\underline{x}} < t^{pc} < \underline{x}$.

2.2.3 Risk-sharing through Credit Contracts, $k^1 > k$

The previous subsections shows that when the merchant must rely on external funds for all the venture's capital requirements because of a shortage of his owns ($k^1 = 0$), the sea loan or the commenda— one or the other depending on the information structure— are corner solutions. Not only is the financier consuming all the second-date endowment in the case of a navigation accident ($\tilde{c_y^2} = w_y$), but both parties would have been better off if more resources had been allocated to his consumption in this state. This implies that a contract with higher repayment in case of navigation loss— which provides less navigation insurance to the merchant than the sea loan and the commenda— would have been Pareto improving. However, such contract is not feasible because the merchant is already paying with everything he has, meaning the very low or zero proceeds of the venture ($\tau_y = y$).

When the merchant is initially endowed with more resources, $k^1 > k > 0$, the total navigation endowment $w_y = k^1 + k^2 - k + y$ gets larger and the constraint $c_y^2 \leq w_y$ cease to be binding in the optimum. An interior optimal allocation (c_y^{2*}, c_x^{2*}) can then be achieved, with $c_y^{2*} > \tilde{c_x^2} = w_y = k^2 - k + y$ and $c_x^{2*} < \tilde{c_x^2}$. Therefore, individually-rational optimal allocations with $k^1 > k > 0$ will no longer entail raising funds for the whole trading venture ($\tau^* \neq -k$) through sea loan or commenda contracts. Yet, these allocations (c_y^{2*}, c_x^{2*}) can still be achieved through a sea loan or a commenda providing only part of the capital requirements. The merchant finances part of the venture himself and bears its corresponding navigation risk, thus effectively receiving less navigation insurance. In particular, proposition 3 holds.

Proposition 3 *The optimal event-contingent allocation of consumption when $k^1 > k$ can be attained by self-financing part of the venture $\phi^* \in (0, 1)$ and raising external funds through a sea loan (if $\theta = 0$) or a commenda (if $\theta = 1$) for the rest of the capital requirements $\tau^* = -(1 - \phi^*)\, k > -k$.*

Graphical analysis

When the merchant is initially endowed with $k^1 > k > 0$, there are more resources in the economy than when he does not have any initial wealth, $k^1 = 0$, so that the corresponding Edgeworth Box is larger. Figure 3 represents both the Edgeworth Boxes for parameters $\lambda_{k^1=0}$ (with $k^1 = 0$) and $\lambda_{k^1>k}$ (with $k^1 > k > 0$), although for ease of exposition the noncontractible area is not depicted under the hidden information scenario ($\theta = 0$).[11]

[11] Alternatively, figure 3 can be thought of as representing a face of the Edgeworth Boxes for a given value of $c_{\bar{x}}^2$ under full information ($\theta = 1$). In this case there are three events for both agents and the contract curve must be represented in a 3-dimensional Edgeworth Box. However, as we are looking at a binding

Because of DARA, the indifference curves of the merchant become flatter as he receives more initial wealth, while those of the financier are unaltered by any increase of the merchant's wealth. Therefore, the contract curve for interior points for parameters $\lambda_{k^1>k}$ lies below the contract curve for $\lambda_{k^1=0}$. The previous subsections shows that the contract curve for $k^1 = 0$ can be represented by $CC_{\lambda_{k^1=0}}$, when a venture is risky and costly, and both agents are risk-averse. Therefore, the contract curve for $k^1 > k$ will be characterized by $CC_{\lambda_{k^1>k}}$ (see $CC_{\lambda_{k^1>k}}$ and $CC_{\lambda_{k^1=0}}$ in figure 3).

[Figure 3 around here]

The individually-rational allocations, in addition to belonging to the contract curve, must satisfy the individually-rational participation constraints, which, as noted before, are more restrictive than the ex-ante participation constraint for the merchant. The merchants' individually rational constraint (5) takes into account the technological and financial ability of the merchant to undertake the project alone. Therefore, any individually rational allocation must provide him with at least the same utility he would get by financing the venture himself and taking all its profits and risks. Yet, the merchant will voluntarily exchange with the financier because financial contracting leads to mutually beneficial risk-sharing.

The core of this simple economy will be thus characterized by the interval $[BP^1, BP^2]$ on the contract curve, where the point BP^i is the individually-rational optimal allocation when agent i has all the bargaining power (see figure 3). In other words, the lower bound of the interval to which $\overline{U}^2$ belongs remains $U^2(k^2)$ but its upper bound is now given by the merchants' individually-rational constraint (5). When the financier has all the bargaining power, the optimal event-consumption allocation BP^2 lies on the indifference curve of the merchant providing him with his minimum individually rational expected utility $E[U^1(k^1 - k + s)]$ (see point A and BP^2 in figure 3). By construction of the contract curve, this merchant's indifference curve intersects at BP^2 with the financier's indifference curve assigning him the individually-rational maximum value of $\overline{U}^2$.

From inspection of figure 3, it follows that the optimal allocation BP^1 reached when the merchant exercises all the bargaining power, $\overline{U}^2 = U^2(k^2)$, is such that that $c_y^{2*} > k^2 - k + y$ (see appendix C). Also, the optimal allocation BP^2 reached when the financier exercises all the bargaining power is such that $c_y^{2*} < k^2$. Thus, any allocation in the core satisfies lemmaq 1, which is proved in appendix C.

restriction for only one event, we can abstract from the optimal relationship between $c^2_{\bar{x}}$ and $c^2_{\underline{x}}$ given by the Kuhn-Tucker conditions of program 3 (in the appendix) and draw the optimal allocation in an intuitive 2-dimensional Edgeworth Box with coordinates $c^i_y, c^i_{\underline{x}}$.

Lemma 1 $k^2 - k + y < c_y^{2*} = k^2 - (1-\phi^*)\,k + \tau_y^* < k^2$

In sum, the optimal allocation of risk can be attained by letting the merchant finance a part $\phi^* \in (0,1)$ of the capital requirements and raise additional funds ($\tau = -(1-\phi^*)k$) through a sea loan (if $\theta = 0$) or a commenda (if $\theta = 1$) contract with $\tau_y^* = y$.

3 Empirical Evaluation of the Theoretical Model

The theoretical model assumes that financial relations were governed by the State's ability to verify information and predicts both the alternative use of the sea loan or the commenda contract given the underlying institutions and the transition from the former to the latter in response to institutional changes that enhanced the State's ability to verify information. This section, first, identifies various institutional arrangements that generated and transmitted the verifiable information required for the Venetian State to adjudicate commercial disputes and, second, documents changes in the selection of contracts in response to institutional changes.

3.1 Institutional arrangements

During the initial phase of the Venetian trading expansion commercial returns were highly uncertain and subject to information asymmetries in the form of hidden information. Merchants were initially the only ones to know *(i)* their true cost of trading in foreign lands, including the bribes paid in port, storage fees, the conversion rate used among various units of account, and so on and so forth, *(ii)* the conditions and the amount of their goods at the port of sale, and *(iii)* the price received and paid for their wares. However, trading overseas became progressively a public affair. It was a cumulative process of institutional development that began as the twelfth century turned to its closes and was completed by the first quarter of the thirteenth century. Long-distance trade, in particular, became carefully monitored by State's delegates in the Venetian colonies abroad, scribes en-route, and public mediators in Venice. Hence, these public officials could and did provide verifiable information regarding commercial disputes.

First, until the last two decades of the twelfth century very few Venetians resided outside Venice and the State had not yet developed permanent administrative and judicial structures abroad. Even in the most frequented and privileged Byzantine markets and in the Crusaders States— where the Venetians obtained large compounds in various cities and enjoyed full extrateritoriality— the Venetian population was predominantly mobile. Although merchants remained abroad for long periods to dispose of wares and find return cargoes, the bulk of the documented Venetians are said to be residents in the various neighborhoods of Rialto. Venetian judges did not settle permanently in Constantantinople until 1186 and notaries voyaged with merchants for most of the twelfth century. Within Moslem lands, trading ventures were sporadic and characterized by flying trips to unfriendly places and speedy returns to the safety of home. As a result, merchants could falsely allege to have paid arbitrarily high custom duties and bribes; claim that their goods were stolen from their warehouse or that storage fees were unpropitious; introduce "noise" through the exchange rates and the conversion of various weights and measures; etc.

However, by the end of the twelfth century the number of Venetians residing outside Venice began to increased. They were not only merchants and sailors but also judges, notaries, consuls, and other public officials who had the duty to oversees commerce, avoid fraud and foster the Venetian interests abroad. Ambassadors and wise men from Venice began to run the public and private administration of their developing commercial empire and, as the thirteenth century progressed, they acquired legal jurisdiction within their colonies.

After the death of Byzantine Emperor Manuel Comnenus in 1180 the Empire was on the point of relentless decay. Its old splendor had already been shaken by the opening of new trading routes when the combination of an ill administration with the re-emergence of various foes in their frontiers impaired its ability to effectively rule over its territory. In 1183 the new Emperor welcomed the Venetians to their old quarter in Constantinople and renewed their suspended privileges. The Venetians were growing wealthy and powerful, but remained under Byzantine jurisdiction until 1205. Following the sack of Constantinople by a crusading army commanded by the ruler of Venice himself, Venice acquired one half and a quarter of the former Byzantine territory and enjoyed a trading monopoly all over it Despite her nominal dominion, Venice only claimed certain enclaves along the route to the Levant, which she came to fully exploited and controlled by the third decade of the thirteenth century (only her domination over Crete was disputed as late as 1236). In contrast with the former Venetian colonies, those acquired in the partition of the Byzantine Empire were immediately placed under governors sent out from Venice, and these ruled in accordance with a well-developed Venetian system of law: a *podestà* was installed in Constantinople in 1205, a *castellano* in Coron and Modon in 1208, a *bailo* in Negroponte in 1216, a duke in Crete in 1219, and consuls continued to be appointed to govern Venetians abroad.

Trade with the Moslem world gained a new impetus under the rule of Elmelik el-Adil during the thirteenth century. Although the Venetians had visited Alexandria and other Moslem ports as far back as the ninth century, they did not enjoyed any special privilege or property until the 1170's, when Saladin conceded them a *fondaco*— a walled enclosure that served as a combined warehouse and hostel— in Alexandria. Yet, the Venetians had no official representation and trade remained highly dependent on the rapacity of foreign tax authorities and population until 1200. Under the more propitious rule of Saladin's brother Elmelik el-Adil, trade flourished in such a way that the Venetians found it necessary to enlarge their colony in Alexandria and sought new privileges. In 1208 Venice was granted a second *fondaco*— built and maintained by the Egyptian authorities—, a reduction in taxes, and the right to judge their own members. A more stable political environment reduced the frequency with which merchandise was improperly hold in the customs. What is more, the Venetians were also granted the right to directly apply to the Egyptian ruler, who was particularly friendly towards Latin merchants, in the case their privileges were abused by local officers or the native population.

In addition, standardized weights and measures were enforced in Venice by the Justices (*Giustizieri*), three public officials instituted by the ruler of Venice Doge Sebastiano Ziani in 1173 to police markets. In the former Byzantine territory and in Alexandria the Venetians came to be granted the right to use their own weights and measures in 1205 and in 1208, respectively. Also, the Venetian big silver penny, the *grosso*, was introduced around the year 1200 and soon became an accepted medium of exchange and unit of account throughout the eastern Mediterranean.

These institutional arrangements, however, did not crystallized all at once but they rather developed progressively as overseas trade became well-established throughout the various Venetian *fondaci* and colonies in the Levant. By the third decade of the thirteenth century Venice had already consolidated her commercial and colonial empire in the East. As a result, a merchant falsely reporting higher costs because of excessive bribes, thefts by the local population or arbitrary exchanges of units of accounts was very likely caught on charges of fraud by the Venetian authorities abroad.

A second source of information asymmetry derived from the conditions and the amount of the goods upon their arrival. Merchants could falsely report that their goods were damaged in transit because not well sheltered while on voyage or claim that a substantial part of their merchandise was pilfered by the sailing crew. To reduce the risk of damage, the Statutes of the thirteenth century—first sanctioned in 1223— regulated the dimension of ships and the distribution of space between cargo, equipment and officials; the cargo allowed in each particular type of ship; the way to load and unload merchandise; etc. The Statutes also retained the captain liable for the goods registered by the scribe of the ship, except for loss at sea, from fire, or the actions of enemies beyond the control of the captain. Therefore, by the third decade of the thirteenth century merchants could no longer claim low profits because their cargoes were unsheltered on board or spoiled while loading and unloading without incurring in a formal accusation against the captain.[12]

Although scribes had accompanied ships during the twelfth century on a regular basis, the Statutes of the thirteenth century conferred them public powers and made their presence compulsory on all big ships.[13]

Scribes thus ranked as petty officers whose records could be consulted for legal disputes. In court their reports prevailed over any other testimony. In 1363 a member of the crew of a galley routed on a voyage to *Romania* was brought into court for loading an unauthorized cargo. The master of the galley backed his crewman but the scribes did not. As a result, the court sentenced against the crewman and fined him accordingly; this, regardless of the bitter protest of the galleys' master, who, as such, enjoyed political and social influence and happened to be the Vettor Pisani who had achieved the most prestigious naval commissions [see Hocquet, 1991, p.491].

The scribes did not only monitor the execution of the very detailed maritime regulations and certify those abstracts which developed on the bill of lading— rendering the captain responsible for the merchandise registered and giving incentive for merchants not to hide cargo—, but they had also the special duty to obstruct fraud in credit agreements. In addition, the scribes registered the number, weight, owner and stamp of any merchandise loaded and unload, as well as the transactions among the merchants on voyage.

Therefore, merchants could not "easily falsify the return by first dropping some of the acquired commodities at another location" (as assumed by Lacker and Weinberg [1989, p.1346]. Moreover, Venetian ships were forbidden to unload cargoes anywhere inside the Adriatic except in Venice. To enforce this prohibition, naval patrols coerced traffic in the

[12]St. dello Zeno (c. 51) ed. by Predelli and Sacerdoti [1902].

[13]The Statutes of the Doge Tiepolo (1223) made it compulsory for each shipowner to appoint one scribe who had to be approved by the Merchnats' Consuls or by a competent Venetian authority if abroad (1233). The Maritime Statutes of the Doge Zeno (1253) had scribes inducted by the *Consoli dei Mercanti* and increased their number to two to further avoid fraud by recording data through two independent public officers. Like all other public officials, the scribes had to give an oath of impartiality and good behavior and were subject to retirement from office if caught in fraud.

northern Adriatic from as early as 1180. In the thirteenth century, there were thirteen control points around the lagoons. At each, a half dozen men with two or three vessels inspected all passers to make sure that their cargoes were covered by permits to go where they were headed and require proof that they had been cleared in Venice [see Lane, pp.59-62]. In addition, ships used for long-distance trade between Venice and the East commonly voyaged on convoy for safety and those of 100 tons and above were required to join the State's fleet by law in 1223.[14] These convoys followed a very detailed itinerary through the many enclaves that Venice had achieved in the Mediterranean and, hence, were subject to direct controls by the Venetian public representatives both during the voyage and at the ports of call.

Third, at the beginning merchants also had hidden information regarding the price received and paid for their Levantine wares. Even though other merchants could testify the prices at which they had traded their own goods, they could very difficultly asses the actual price faced by their fellows because shocks in supply and demand led to large changes in prices, even in competitive markets like those of Byzantium, Alexandria or Venice. For example, a delay in the arrival of the convoy bringing a large supply of pepper and other species from Alexandria to Venice in 1225 caused a wide increase in prices all over the West [Lopez, 1976].

Yet, the State could verify prices by that time, for government officials mediated all (legal) transactions in Venice no later than 1225. It was illegal to transact without the intervention of *sensali della messetteria*, who amounted to at least forty in the market place of Rialto during the thirteenth century [Rösch, 1991, p. 453]. These brokers made sure that sale taxes were paid and that merchants did not break the law. Although there is no evidence of their operation outside Venice, one can guess that other Venetian authorities abroad performed a similar monitoring role. No doubt, Venetian merchants were subject to the rules, regulations, and controls of the motherland in the Venetians colonies. Moreover, the Statutes established that, in the absence of *Consoli dei Mercanti* or other specific government officials abroad, the colonial governors must substitute them in their duties to control trade. Venetian trade was so heavily regulated as to enable the Venetians to establish a State's monopsony over pepper in Alexandria in 1288. Thereafter, all Venetian merchants acted as a single buyer and faced the very same publicly registered price of pepper in the most profitable "market of the worlds." From 1283 the Venetians also practiced a similar monopsony in the acquisition

[14] Even those small ships which were not subject to State's regulation tended to voluntarily join the State's fleets, since voyaging in convoy under the protection of armed forces provided by the State reduced the risks at sea and from the action of enemy people.

of cotton in Acre [Day, 1984; and Rösch, 1991].

On the top of this spreading bureaucracy were the consuls of the merchants, who are first mentioned in 1228. In Venice the consuls did not emerge privately as the head of the merchant guild, which never existed in Venice, but they were rather appointed as government officials with the duty of controlling commerce and enforcing the law, including the prevention of fraud in credit agreements for long-distance trade. If they found a merchant guilty of breaking the maritime regulations or breaching their financial contracts— including the commenda— they could and did prohibit the particular merchant from joining the State's fleet, which actually meant exclusion from the Venetian very unique commercial privileges. In addition, they could initiate a lawsuit against the cheat [González de Lara, 2001].

3.2 Contractual arrangements

The evidence reported in the previous subsection suggest three periods of institutional development. First, until the 1180's the State could hardly verify the true commercial return (financial relations were characterized by a commitment problem in the presence of hidden information). Second, during the period of transition from 1180 to, say, 1223, various institutional arrangements gradually generated and transmitted the verifiable information required to mitigate this information asymmetry. Finally, by the third decade of the thirteenth century the State could fairly verify venture's commercial returns. The theoretical model captures these different State's ability to verify information and predicts the predominance of non-commercially contingent sea loan contracts until 1180, the prevalence of commercially-contingent commenda contracts after 1223, and a period of contractual transition in between, which is exactly what we observe (figure 4). Empirical confirmation of these predictions thus lends support to the thesis that institutional changes that enhanced the State's ability to verify information actually led the transition form the sea loan to the commenda and facilitated a better allocation of risk.

Although the evidence reported in figure 4 is compelling, one might still question the non-insignificant use of the commenda during a period in which the Venetians had not yet established administrative and judicial structures abroad and trade was not yet heavily regulated and directly controlled by the State. Indeed, the State, in and by itself, could have hardly enforced commenda contracts prior to the close of the twelfth century. Most likely, family ties and special relationships of trust between particular merchants and their financiers provided a further bond for the compliance of these early commenda contracts.[15]

The heavy increase in the volume and value of trade that experimented Venice from the end of the twelfth century onwards, however, was sustained by a State-based mechanism for contract enforcement that supported financial relations beyond those which could have been enforced by the family or reputation mechanisms.

FIGURE IV
Documented Sea Loan and Commenda Contracts and their Distribution over Time

That the commenda replaced the sea loan in response to changes in the State's ability to verify information is further confirmed by the fact that all merchants who obtained the State's approval— *licentiam*— to join a State's convoy financed their venture through commenda contracts. These convoys were organized and protected by the State and round traveled from Venice to well-established Venetian colonies in the East. Therefore, those merchants who joined the State's convoys were placed under the direct control of government officials, who could thus evaluate the true profitability of venture's returns. Conditioning funds through commenda contracts on the merchants' attainment of a these State's licenses was increasingly common during the thirteenth century, dating from 1200 the first record establishing this requirement explicitly.

[15] Almost twenty percent of the commenda contracts signed during the period 1121-1180 were among family members, whereas kinship ties are present only in ten percent of the whole-sample contracts. Also, the evidence suggests a permanent relationship between some of the financiers and the merchants to whom they entrusted their funds. For example, in 1130 a certain Petrus Adoaldus settled a bilateral commenda with the merchant Viviano da Molin, who had traded and done business at their common profit in Acre for two years (Morozzo della Rocca and Lombardo [1940, doc. 59]. Contracts were commonly signed for a round-trip voyage, so that a long-term contract might well reflect particular trading relationships. Also, the fact that the financier of a bilateral commenda signed in 1169 for a venture from Constantinople to Armiro resided (*habitator*) in Constantinople indicates that he belonged to a particularly well-informed net of active merchants in the Levant [Morozzo della Rocca and Lombardo, 1940, doc. 236]. The evidence, however, indicates that these mechanisms for contract enforcement were complementary to the State, rather than been substitutes. For a complete development of this topic, see González de Lara [2001].

Furthermore, the evidence reported in table 1 indicates that during the whole thirteenth century, ventures departing from Venice were regularly financed through commenda contracts, whereas the more hazardous ventures that concentrated on the trades that did not passed through Venice itself tended to be financed through sea loan contracts. The first observation is consistent with the theoretical reasoning to the extent that *(i)* before leaving port in Venice, ships had to pass inspection to make sure that they were not overloaded and that all the maritime regulations were fulfill, including the presence of the ships' scribes, *(ii)* thirteenth-century ventures departing from Venice were commonly organized in State's convoys— even though the records do not always require the merchants to trade under the State's supervision, *secundum licentiam*— and *(iii)* merchants were usually required to either brought back or dispatch the commenda proceeds to Venice, where State brokers registered the sale prices of their Levantine wares.

TABLE I
Contracts Financing Ventures to Egypt

Period	sea loan	commenda
twelfth century	91%	9%
1200-1214	6%	94%

Likewise, the facts that *(i)* the State's maritime regulation were more easily bypassed outside Venice political and economic center, and *(ii)* ventures originating outside Venice involved trading in far-off and unfamiliar marts where Venetian administrative and legal representation was absent and to which no convoy was organized are theoretically consistent with the prevalence of the sea loan for these trades (see column 3 of table 1). This is particularly meaningful because prior to the implementation of the institutional arrangements that later enhanced the State's ability to verify information, sea loan contracts were used for all kind of ventures: during the period 1121-1180, sea loan contracts were used to finance 79 percent of the ventures departing form Venice and 77 per cent of ventures departing from outside Venice. However, as the State's ability to verify information increased, sea loan contracts— which were progressively replaced by commenda contracts (see column 4 of table 1)— were relegated to finance those ventures that originated outside Venice and whose commercial returns were, thereby, non-verifiable.[16] For example, one of the latest sea

[16]Only two sea loan contracts have been computed as having financed ventures departing from Venice during the period 1121-1261. This 1 percent is a very conservative measure for these two contracts, over a

loan contracts in the sample was signed between a group of Venetians merchants and two Florentines in Tunis in 1245 [Morozzo della Rocca and Lombardo, 1940; docs. 776 and 777]. Although the Venetians enjoyed some privileges in Tunis from 1231, they were not really active there until the fourteenth century and protective convoys were never organized.

The fact that the above mentioned financiers were non-Venetians involved an additional difficulty to the enforcement of this very rare sea loan contract. Indeed, the theoretical framework predicts that financiers with higher access cost to the State-based institutions for contract enforcement would tend to participate less in trade and contract through sea loans. Non-Venetians had, indeed, a much more difficult access to the Venetian court system, for medieval government officials and judges were typically biased in favor of locals, and Venetian law prohibited foreigners to both sue a Venetian in an ordinary court and testify against Venetians at any court.[17] Also, if financial relations were actually governed by the State's ability and willingness to verify information, one would expect that the few non Venetians who dared risk their capital in Venetian sea ventures relied on simple sea loan contracts, for inter-community disputes from failed commenda contracts were more difficult to settle in court than those involving less-complex sea loan contracts. Consistent with these predictions, we observed that 98 percent of all the financiers appearing in the historical source were Venetians and the very few foreigners were, in general, somewhat attached to Venice by residing at its political and economic center, and used sea loan contracts.[18]

Finally, it is worth noting that although the transition from the sea loan to the commenda was a lengthy process (it took about four decades), it did not reflect adaptive learning. Rather, the selection of alternative contracts was the direct and immediate optimal response to institutional changes: once the institutional environment enabled the State to verify the commercial return, better risk-sharing commenda contracts were introduced without delay. Identifying an institutional breaking point is, however, challenging because of the many cumulative institutional developments that enhanced the State's ability to verify information. The trade with Egypt offers the best possibility to identify such an institutional breaking

total of 7 sea loans for the period, were recorded in documents that omit both the destination of the trip and the date the document of obligation was signed; hence I have classified them as belonging to the period from which our documentation originated without really knowing their exact date.

[17]This does not mean that there was no inter-community "justice" but, no doubt, it was more costly and uncertain than intra-community relationships [see Greif, 1998].

[18]Five of the six known financiers from outside Venice contracted through sea loans. The remaining one came from Bologna, with which Venice had especially good relations, and signed the only commenda contract that entitled merchants to a bigger share than the standard one quarter of profits during the thirteenth century. On the other hand, the only two contracts signed by non-Venetian merchants residing outside the lagoon were sea loans.

point. Due to political events abroad— Elmelik-el-Adil inherited the dominion over Syria, Palestine and Egypt from his brother Saladin and proved himself much more propitious towards Latin merchants— at a point in time when the Venice's institutional organization had matured, the information structure faced by the Venetians in Alexandria changed suddenly in 1200. A corresponding shift in the selection of contractual forms followed.

TABLE II
Relative Representation of Sea Loans (s.l.) by Place of Departure

Period	% of s.l. over ventures departing from Venice	% of s.l. over ventures departing from outside Venice	Total % of s.l.
1121-1180	79 %	77 %	76 %
1181-1220	17 %	56 %	29 %
1221-1261	1 %	71 %	4.6 %

As noted in Table 2, more than 90 percent of the trading ventures explicitly led to Egypt during the twelfth century were financed through sea loans, whereas more than 90 percent of those undertaken during the thirteenth century were funded through commenda contracts. After 1214 Egypt is no longer explicitly mentioned in documents recording sea loan or commenda contracts, although we know that the route to Egypt was the busiest and most profitable at the time. In reality, many of the numerous commenda contracts which left the venture's destination free, as long as the merchant joined the state's convoys, during the thirteenth century were directed to Alexandria, even after 1214. This confirms that the replacement of the sea loan with the commenda actually took place by the turn of the twelfth century in response to changes in the State's ability to verify information.[19]

[19] Alternatively, one might want to study a structural change in 1208 after the signature of the commercial treaty described in section 3.1. No doubt this treaty enhanced the State's ability to enforce contracts with contingent transfers like the commenda by *formally* recognizing the legal authority of Venetian public officials to settle disputes among Venetians, by granting them the privilege of applying to the rulers' court whenever their property rights were abused by the local tax authorities and population, and by enabling the Venetians to use their own weights and measures. Yet, this treaty sanctioned an earlier *de facto* more propitious economic and political attitude from the new Egyptian ruler toward the Venetians. Moreover, treaties are not signed unexpectedly, so their consequences can be anticipated. Finally, the trend showed in table 2 persists for a point-break in 1208. Data are very incomplete: there is one observation at 1200 and a jump afterwards to 1205, with relatively rich evidence until 1214.

4 Conclusions

In late medieval Venice the State functioned as an enforcement and information-transmission mechanism. Venice's exclusive trading rights in various localities abroad and restrictions on entry provided Venetian merchants with the stream of rents required to induce them to retain their affiliation with the city, where the State could and did exercise fully its coercive power.

Furthermore, the Venetian State established various institutional arrangements— such as administrative and judicial structure, both in Venice and abroad; regulations; and State's direct controls over trade— that generated and transmitted the verifiable information required to adjudicate commercial disputes. From the end of the twelfth century onwards overseas trade became gradually a public affair. State delegates in the Venetian colonies abroad, scribes en-route, and public mediators in Venice carefully monitored commercial ventures in each and all of their phases. The resulting enhanced State's ability to verify information, however, did not crystallized all at once, but it rather developed incrementally as overseas trade became well-established throughout the various Venetian colonies in the Levant, and as trading voyages were organized in State's round convoys from Venice to the Venetian enclaves in the East. As a result, the commenda contract progressively acquired prominence as the twelfth century turned to its close and prevailed by the third decade of the thirteenth century, when Venice had consolidated her commercial and colonial Empire in the East.

The sea loan and the commenda sustained the optimal allocation of risk, given their underlying institutional foundations and the very specific character of long-distance trade during the twelfth and thirteenth centuries. First, the presence of indivisible ventures subject to aggregate risk limited the ability to diversify and prevented agents from effectively becoming risk-neutral, as it is usually assumed in Finance. Neither the sea loan nor the commenda— with repayment equal to all the capital saved from misfortune in the case of loss due to the "risk of sea and people"— would have been optimal if (on the margin risk-neutral) financiers could have diversified the idiosyncratic risks faced by each (risk-averse) merchant; rather, it would have been optimal that the financier provided full insurance to the merchant against the "risk of sea and people."

Second, trading ventures were highly costly and risky. As a result, (risk-averse) merchants who were constrained to rely on external funds because of a shortage of their owns, could not repay any amount above the venture's returns, even though this was dreadfully insufficient to reward the financier's capital investment in the case of loss at sea or from the action of the enemy. To compensate for this, the (risk-averse) financier called for soaring payments when the merchandise arrived at port safe and sound. As a consequence, his consumption varied widely, whereas that of the merchant was invariably small. The lesser the amount paid out in the case of loss due to the "risk of sea and people," the higher the repayment required otherwise and the less smoother/smoother the financier's/merchant's event-consumption. Because both agents were equally risk averse, the financier valued consumption in the event of loss at sea or from the action of the enemy relatively more than the merchant, and it was optimal that the merchant repaid all what was retrieved from misfortune. Therefore, the sea loan and the commenda emerge optimally.

Yet, these contractual forms provided too much insurance to the merchant against the "risk of sea and people." Both the merchant and his potential financier would have preferred a contract with higher repayments in the case of loss while at sea or from the action of the enemy, but this was not feasible when the merchant lacked the resources required to fund the venture (the sea loan and the commenda are corner solutions). This explains why merchants endowed with some resources did not raise funds for the whole trading venture through sea loan or commenda contracts. On the contrary, they optimally financed part of their venture themselves and bore the corresponding risk, thus effectively receiving less insurance against the "risk of sea and people."

Apart from the better historical understanding of the transition from the sea loan to the commenda, this paper has a contribution to both the institutional and the contract theory literatures. First, it complements the Historical Institutional Analysis, initiated by A. Greif, by providing an adequate theoretical framework to evaluate the nature, transition, and efficiency implications of various historically relevant contracts. At the same time, it adds to the New Institutional Economics, as developed initially by North and Williamson, by indicating the necessity of studying institutional and contractual changes in a combined manner. Institutional developments that enhanced the State's ability to verify information led the transition from the sea to the commenda. Thus, this paper reveals the paramount influence of changing institutions on the extent to which contracts providing the appropriate incentives and risk allocations were possible.

Yet, institutions are exogenous in the model. Although the empirical part goes beyond a simple exercise on comparative statics by investigating the dynamic process of institutional change and the corresponding process of adjustment in the use of contracts, further research is needed on the self-reinforcement dynamics that induced the Venetians to endogenously provide verifiable information.

Second, in contrast with the standard static explanations of Optimal Security Design,[20] this paper links the selection and transition of various contracts to their underlying institutional foundations. In addition, the paper accounts for the observed capital structure, which entailed the merchant's funding of part of the venture and the raising of the remaining capital through sea loan and commenda contracts, meaning through debt and equity. Existing models in Optimal Security Design offer static theories of debt or equity, but they hardly rationalize the simultaneous use of both contractual forms (exceptions are Chang [1992] and Dewatripont and Tirole [1994]). Furthermore, these models predict an extreme inside participation rate: either the (risk-neutral) merchant avoids conflicts of interest by investing all his wealth in the venture he manage before resorting to outside funding or he (being risk-averse) does not finance the project at all and receives full insurance through a non-contingent salary payment. In my model, however, both the merchant and his potential financier are risk averse to capture the details of the historical context and hence accounts for the observed capital structure.

A Proof of proposition 1

Let parameter values $\hat{\lambda} = (\hat{\theta}, \hat{k^1}, \hat{k}, \hat{y}, \hat{p}_y, \hat{\underline{x}}, \hat{\bar{x}}, \frac{\hat{p}_{\bar{x}}}{\hat{p}_{\underline{x}}+\hat{p}_{\bar{x}}})$ with $\hat{\theta} = 0$ and $\hat{k^1} = 0$ be such that the sea loan contract does not sustain program 2's optimal allocation of consumption, $(\hat{c}_y^2, \hat{c}_x^2)$. Then, $\hat{c}_y^2 < \hat{w}_y$, as draw in figure 2 for CC', and necessary and sufficient Kuhn-Tucker conditions lead to

$$\begin{aligned}
\frac{\partial \pounds(\eta,\mu_y,\mu_x,c_y^2,c_x^2;\lambda)}{\partial \eta} &= -\overline{U}^2 + E[U^2(c_s^2)] = 0 \\
\frac{\partial \pounds(\eta,\mu_y,\mu_x,c_y^2,c_x^2;\lambda)}{\partial c_y^2} &= -p_y U^{1\prime}(w_y - c_y^2) + \eta\, p_y U^{2\prime}(c_y^2) - \mu_y = 0 \\
\frac{\partial \pounds(\eta,\mu_y,\mu_x,c_y^2,c_x^2;\lambda)}{\partial c_x^2} &= -[p_{\underline{x}} U^{1\prime}(w_{\underline{x}} - c_x^2) + p_{\bar{x}} U^{1\prime}(w_{\bar{x}} - c_x^2)] + \eta(1-p_{y)} U^{2\prime}(c_x^2) - \mu_x = 0
\end{aligned} \tag{10}$$

evaluated at $\hat{\eta}$, $\hat{\mu}_y = \hat{\mu}_x = 0$, $\hat{c}_y^2$, $\hat{c}_x^2$, and $\hat{\lambda}$, where η, μ_y, and μ_x are the Lagrangian multipliers associated with restrictions (7) and (8), respectively, and $\pounds(.)$ is the Lagrange function associated with Program 2.[21]

Let λ varies in an open neighborhood of $\hat{\lambda}$ such that the pattern of binding and slack constraints of program 2 does not change. Totally differentiating (10) and applying the Implicit Function Theorem, one can calculate the comparative statics effects of each parameter value λ_i on c_y^2 at a solution point $(\hat{c}_y^2, \hat{c}_x^2)$ and parameter values $\hat{\lambda}$ with $\hat{\eta} > 0$, $\hat{\mu}_y = \hat{\mu}_x = 0$,

[20] For excellent overviews, see Harris and Raviv [1991] and Freixas and Rochet [1997].

[21] This assumes that for parameter values $\hat{\lambda}$ the solution of program 2 is such that $\hat{c}_x^2 < \hat{w}_{\underline{x}}$. The case for which $\hat{c}_x^2 = \hat{w}_{\underline{x}}$ can be easily derived by adding restriction $\frac{\partial \pounds(\eta,\mu_y,\mu_x,c_y^2,c_x^2;\lambda)}{\partial \mu_x} = 0$ to (10).

and $d\mu_y = d\mu_x = 0$:

$$\frac{dc_y^2}{d\lambda_i} = -\frac{\left|\hat{\overline{H}}_{\lambda_i}\right|}{\left|\hat{\overline{H}}\right|},$$

where

$$\left|\hat{\overline{H}}_{\lambda_i}\right| = \begin{vmatrix} \frac{\partial^2 \pounds(\eta,\mu_y,\mu_x,c_y^2,c_x^2;\lambda)}{(\partial\eta)^2} & \frac{\partial^2 \pounds(\eta,\mu_y,\mu_x,c_y^2,c_x^2;\lambda)}{\partial\eta\partial\lambda_i} & \frac{\partial^2 \pounds(\eta,\mu_y,\mu_x,c_y^2,c_x^2;\lambda)}{\partial\eta\partial c_x^2} \\ \frac{\partial^2 \pounds(\eta,\mu_y,\mu_x,c_y^2,c_x^2;\lambda)}{\partial c_y^2\partial\eta} & \frac{\partial^2 \pounds(\eta,\mu_y,\mu_x,c_y^2,c_x^2;\lambda)}{\partial c_y^2\partial\lambda_i} & \frac{\partial^2 \pounds(\eta,\mu_y,\mu_x,c_y^2,c_x^2;\lambda)}{\partial c_y^2\partial c_x^2} \\ \frac{\partial^2 \pounds(\eta,\mu_y,\mu_x,c_y^2,c_x^2;\lambda)}{\partial c_x^2\partial\eta} & \frac{\partial^2 \pounds(\eta,\mu_y,\mu_x,c_y^2,c_x^2;\lambda)}{\partial c_x^2\partial\lambda_i} & \frac{\partial^2 \pounds(\eta,\mu_y,\mu_x,c_y^2,c_x^2;\lambda)}{(\partial c_x^2)^2} \end{vmatrix}$$

and the (binding-constraints) border hessian $\hat{\overline{H}}$ evaluated at $\hat{\lambda}$ and $(\hat{c}_y^2, \hat{c}_x^2)$ is negative definite: $\left|\hat{\overline{H}}\right| > 0$.

It is proved below that at a solution point $(\hat{c}_y^2, \hat{c}_x^2)$,

$$\begin{aligned} \frac{dc_y^2}{d(k^2-k)} &> 0 \quad \text{but} \quad dc_y^2 < dw_y = d(k^2-k) \\ \frac{dc_y^2}{dy} &> 0 \quad \text{but} \quad dc_y^2 < dw_y = dy \\ \frac{dc_y^2}{dp_y} &> 0 \quad \text{and} \quad dw_y = 0 \\ \frac{dc_y^2}{d\underline{x}} < 0,\ \frac{dc_y^2}{d\bar{x}} < 0,\ \frac{dc_y^2}{d\frac{p_{\bar{x}}}{p_{\underline{x}}+p_{\bar{x}}}} &< 0 \quad \text{and} \quad dw_y = 0. \end{aligned} \tag{11}$$

Therefore, beginning with parameter values $\hat{\lambda}$ for which the sea loan contract is not optimal ($\hat{c}_y^2 < \hat{w}_y$), a change in parameters such that the venture becomes more costly— $d(k^2-k) < 0$— and/or risky— $dy < 0$, $dp_y > 0$ and/or $dE[x] < 0$— leads the new solution to get closer and closer to the border $c_y^2 = w_y$. At a point, the solution will reach the border and the sea loan will be optimal.

However, this tricky point with $c_y^2 = w_y$ and $\mu_y = 0$ is on the boundary between two regions with different patterns of binding and slack constraints. As a result, deviations to the left side will have to be treated using the set of equations (10) with $\mu_y = \mu_x = 0$ and $d\mu_y = d\mu_x = 0$ while totally differentiating, whereas those to the right side using a different set: equation $\frac{\partial \pounds(\eta,\mu_y,\mu_x,c_y^2,c_x^2;\lambda)}{\partial\mu_y} = w_y - c_y^2 = 0$ must be added to (10), which now hold for $\mu_y \geq 0 = \mu_x$ and $d\mu_y \neq 0 = d\mu_x$. If parameter values keep on changing so that the venture becomes even more risky and costly, the sea loan will keep on being optimal, because at a solution point $(\tilde{c}_y^2, \tilde{c}_x^2)$ with $\tilde{c}_y^2 = \tilde{w}_y$, and parameter values $\tilde{\lambda}$ with $\tilde{\eta} > 0$, $\tilde{\mu}_y \geq 0$, $\tilde{\mu}_x = 0$, and $d\mu_x = 0$,

$$\frac{dc_y^2}{d\lambda_i} = -\frac{\left|\tilde{\overline{H}}_{\lambda_i}\right|}{\left|\tilde{\overline{H}}\right|},$$

where

$$\left|\tilde{\overline{H}}_{\lambda_i}\right| = \begin{vmatrix} \frac{\partial^2 \pounds(\eta,\mu_y,\mu_x,c_y^2,c_x^2;\lambda)}{(\partial\eta)^2} & \frac{\partial^2 \pounds(\eta,\mu_y,\mu_x,c_y^2,c_x^2;\lambda)}{\partial\eta\partial\mu_y} & \frac{\partial^2 \pounds(\eta,\mu_y,\mu_x,c_y^2,c_x^2;\lambda)}{\partial\eta\partial\lambda_i} & \frac{\partial^2 \pounds(\eta,\mu_y,\mu_x,c_y^2,c_x^2;\lambda)}{\partial\eta\partial c_x^2} \\ \frac{\partial^2 \pounds(\eta,\mu_y,\mu_x,c_y^2,c_x^2;\lambda)}{\partial\mu_y\partial\eta} & \frac{\partial^2 \pounds(\eta,\mu_y,\mu_x,c_y^2,c_x^2;\lambda)}{(\partial\mu_y)^2} & \frac{\partial^2 \pounds(\eta,\mu_y,\mu_x,c_y^2,c_x^2;\lambda)}{\partial\mu_y\partial\lambda_i} & \frac{\partial^2 \pounds(\eta,\mu_y,\mu_x,c_y^2,c_x^2;\lambda)}{\partial\mu_y\partial c_x^2} \\ \frac{\partial^2 \pounds(\eta,\mu_y,\mu_x,c_y^2,c_x^2;\lambda)}{\partial c_y^2\partial\eta} & \frac{\partial^2 \pounds(\eta,\mu_y,\mu_x,c_y^2,c_x^2;\lambda)}{\partial c_y^2\partial\mu_y} & \frac{\partial^2 \pounds(\eta,\mu_y,\mu_x,c_y^2,c_x^2;\lambda)}{\partial c_y^2\partial\lambda_i} & \frac{\partial^2 \pounds(\eta,\mu_y,\mu_x,c_y^2,c_x^2;\lambda)}{\partial c_y^2\partial c_x^2} \\ \frac{\partial^2 \pounds(\eta,\mu_y,\mu_x,c_y^2,c_x^2;\lambda)}{\partial c_x^2\partial\eta} & \frac{\partial^2 \pounds(\eta,\mu_y,\mu_x,c_y^2,c_x^2;\lambda)}{\partial c_x^2\partial\mu_y} & \frac{\partial^2 \pounds(\eta,\mu_y,\mu_x,c_y^2,c_x^2;\lambda)}{\partial c_x^2\partial\lambda_i} & \frac{\partial^2 \pounds(\eta,\mu_y,\mu_x,c_y^2,c_x^2;\lambda)}{(\partial c_x^2)^2} \end{vmatrix},$$

the relevant border hessian $\tilde{\overline{H}}$ evaluated at $\tilde{\lambda}$ and $(\tilde{c}_y^2, \tilde{c}_x^2)$ is negative definite— $\left|\tilde{\overline{H}}\right| > 0$— and

$$
\begin{aligned}
\frac{dc_y^2}{d(k^2-k)} &> 0 \quad \text{but} \quad dc_y^2 = dw_y = d(k^2-k) \\
\frac{dc_y^2}{dy} &> 0 \quad \text{but} \quad dc_y^2 = dw_y = dy \\
\frac{dc_y^2}{dp_y} = \frac{dc_y^2}{d\underline{x}} = \frac{dc_y^2}{d\bar{x}} = \frac{dc_y^2}{d\frac{p_{\bar{x}}}{p_{\underline{x}}+p_{\bar{x}}}} &= 0 \quad \text{and} \quad dw_y = 0.
\end{aligned}
\tag{12}
$$

It is worth noting that for parameters values such that $\mu_y > 0$, the comparative statics effects given by (12) holds for both parameters's increases and decreases. Therefore, the sea loan contract is optimal for a robust set of parameters: let parameter values $\tilde{\lambda}$ be such that the sea loan is optimal, with $\tilde{c}_y^2 = \tilde{w}_y$, then for parameter values in an open neighborhood of $\tilde{\lambda}$, $\tilde{c}_y^2 + dc_y^2 = \tilde{w}_y + dw_y$.

Show that $\left|\hat{\overline{H}}\right| > 0$ evaluated at $\hat{\lambda}$ and $(\hat{c}_y^2, \hat{c}_x^2)$.

$$
\begin{aligned}
\left|\hat{\overline{H}}\right| &= \begin{vmatrix} 0 & p_y\, U^{2'}(c_y^2) & (1-p_y)\, U^{2'}(c_x^2) \\ p_y\, U^{2'}(c_y^2) & h_{22} & 0 \\ (1-p_y)\, U^{2'}(c_x^2) & 0 & h_{33} \end{vmatrix} = \\
&= -\left[p_y\, U^{2'}(c_y^2)\right]^2 h_{33} - \left[(1-p_y)\, U^{2'}(c_x^2)\right]^2 h_{22} > 0
\end{aligned}
$$

because both h_{22} and h_{33} are negative.

$$
\begin{aligned}
h_{22} &= p_y\, U^{1''}(w_y - c_y^2) + \eta\, p_y\, U^{2''}(c_y^2) = \\
&= -p_y\, R^1(w_y - c_y^2)\, U^{1'}(w_y - c_y^2) - \eta\, p_y\, R^2(c_y^2)\, U^{2'}(c_y^2) = \\
&= -p_y\, R^1(w_y - c_y^2)\, U^{1'}(w_y - c_y^2) - p_y\, R^2(c_y^2)\, U^{1'}(w_y - c_y^2) = \\
&= -p_y \left[R^1(w_y - c_y^2) + R^2(c_y^2)\right] U^{1'}(w_y - c_y^2) < 0
\end{aligned}
\tag{13}
$$

and

$$
\begin{aligned}
h_{33} &= p_{\underline{x}}\, U^{1''}(w_{\underline{x}} - c_x^2) + p_{\bar{x}}\, U^{1''}(w_{\bar{x}} - c_x^2) + \eta\,(1-p_y) U^{2''}(c_x^2) = \\
&= -R^1(w_x - c_x^2)\, U^{1'}(w_x - c_x^2) - \eta\,(1-p_y)\, R^2(c_x^2)\, U^{2'}(c_x^2) = \\
&= -R^1(w_x - c_x^2)\, U^{1'}(w_x - c_x^2) - R^2(c_x^2)\, U^{1'}(w_x - c_x^2) = \\
&= -\left[R^1(w_x - c_x^2) + R^2(c_x^2)\right] U^{1'}(w_x - c_x^2) < 0,
\end{aligned}
\tag{14}
$$

where the first equalities are simply the definitions of h_{22} and h_{33}; the second equalities derive from applying the definition of absolute risk-aversion coefficient, $R(z) = -\frac{U''(z)}{U'(z)}$, and defining

$$
R^1(w_x - c_x^2) = -\frac{U^{1''}(w_x - c_x^2)}{U^{1'}(w_x - c_x^2)} = -\frac{p_{\underline{x}}\, U^{1''}(w_{\underline{x}} - c_x^2) + p_{\bar{x}}\, U^{1''}(w_{\bar{x}} - c_x^2)}{p_{\underline{x}}\, U^{1'}(w_{\underline{x}} - c_x^2) + p_{\bar{x}}\, U^{1'}(w_{\bar{x}} - c_x^2)}
\tag{15}
$$

to make the notation more compact; the third equalities follow from, respectively, the second and third row in (10) with $\mu_y = \mu_y = 0$; the fourths, from simply operating; and the inequality, from $U'(.) > 0$ and $U''(.) < 0$, so that $R^i(.) > 0$, for $i = 1, 2$. **QED**

Note that $\left|\hat{\overline{H}}\right|$ can be expressed as

$$\left|\hat{\overline{H}}\right| = \begin{aligned}[t] & \left[p_y\, U^{2'}(c_y^2)\right]^2\, U^{1'}(w_x - c_x^2)\, R^1(w_x - c_x^2) + \\ & \left[p_y\, U^{2'}(c_y^2)\right]^2\, U^{1'}(w_x - c_x^2)\, R^2(c_x^2) + \\ & \left[(1-p_y)\, U^{2'}(c_x^2)\right]^2\, p_y\, U^{1'}(w_y - c_y^2)\, R^1(w_y - c_y^2) + \\ & \left[(1-p_y)\, U^{2'}(c_x^2)\right]^2\, p_y\, U^{1'}(w_y - c_y^2)\, R^2(c_y^2). \end{aligned} \tag{16}$$

Show that $\frac{dc_y^2}{d(k^2-k)} = -\frac{\left|\hat{\overline{H}}_{(k^2-k)}\right|}{\left|\hat{\overline{H}}\right|} \in (0,1)$ **evaluated at** $\hat{\lambda}$ **and** $(\hat{c}_y^2, \hat{c}_x^2)$**.**

$$\begin{aligned} \left|\hat{\overline{H}}_{(k^2-k)}\right| &= \left[(1-p_y)\, U^{2'}(c_x^2)\right]^2\, p_y\, U^{1'}(w_y - c_y^2)\, R^1(w_x - c_x^2)\ - \\ & \quad \left[(1-p_y)\, U^{2'}(c_x^2)\right]^2\, p_y\, U^{1'}(w_y - c_y^2)\, R^1(w_y - c_y^2) < 0 \end{aligned} \tag{17}$$

because $U'(.) > 0$, $w_y - c_y^2 < w_{\underline{x}} - c_x^2 < w_x - c_x^2$,[22] and utility functions exhibit DARA, so that $R^1(w_y - c_y^2) > R^1(w_x - c_x^2)$.

Comparing (17) with (16) , it follows that $0 < \left|\hat{\overline{H}}\right| + \left|\hat{\overline{H}}_{(k^2-k)}\right|$. **QED**

Show that $\frac{dc_y^2}{dy} = -\frac{\left|\hat{\overline{H}}_y\right|}{\left|\hat{\overline{H}}\right|} \in (0,1)$ **evaluated at** $\hat{\lambda}$ **and** $(\hat{c}_y^2, \hat{c}_x^2)$**.**

$$\begin{aligned} \left|\hat{\overline{H}}_y\right| &= \left[(1-p_y)\, U^{2'}(c_x^2)\right]^2\, p_y\, U^{1''}(w_y - c_y^2) = \\ &= -\left[(1-p_y)\, U^{2'}(c_x^2)\right]^2\, p_y\, U^{1'}(w_y - c_y^2)\, R^1(w_y - c_y^2) < 0 \end{aligned} \tag{18}$$

Comparing (18) with (16), it follows that $0 < \left|\hat{\overline{H}}\right| + \left|\hat{\overline{H}}_{(k^2-k)}\right|$. **QED**

Show that $\frac{dc_y^2}{dp_y} = -\frac{\left|\hat{\overline{H}}_{p_y}\right|}{\left|\hat{\overline{H}}\right|} > 0$ **evaluated at** $\hat{\lambda}$ **and** $(\hat{c}_y^2, \hat{c}_x^2)$**.**

$$\begin{aligned} \left|\hat{\overline{H}}_{p_y}\right| &= \left[U^2(c_y^2) - U^2(c_x^2)\right]\, p_y\, U^{2'}(c_y^2)\, U^{1'}(w_x - c_x^2)\, [R^1(w_x - c_x^2) + R^2(c_x^2)] \\ & \quad - (1-p_y)\, U^{2'}(c_x^2)\, p_y\, U^{2'}(c_y^2)\, \tfrac{U^{1'}(w_x - c_x^2)}{1-p_y} < 0 \end{aligned}$$

because $R^i(.) > 0$, $U^{i'}(.) > 0$, and $c_y^2 \le c_x^2$, so that $\left[U^2(c_y^2) - U^2(c_x^2)\right] < 0$. **QED**

Show that $\frac{dc_y^2}{d\underline{x}} = -\frac{\left|\hat{\overline{H}}_{\underline{x}}\right|}{\left|\hat{\overline{H}}\right|} < 0$ **and** $\frac{dc_y^2}{d\bar{x}} = -\frac{\left|\hat{\overline{H}}_{\bar{x}}\right|}{\left|\hat{\overline{H}}\right|} < 0$ **evaluated at** $\hat{\lambda}$ **and** $(\hat{c}_y^2, \hat{c}_x^2)$**.**

$$\left|\hat{\overline{H}}_{\underline{x}}\right| = -(1-p_y)\, U^{2'}(c_x^2)\, p_y\, U^{2'}(c_y^2)\, p_{\underline{x}}\, U^{1''}(w_{\underline{x}} - c_x^2) > 0.$$

$$\left|\overline{H}_{\bar{x}}\right| = -(1-p_y)\, U^{2'}(c_x^2)\, p_y\, U^{2'}(c_y^2)\, p_{\bar{x}}\, U^{1''}(w_{\bar{x}} - c_x^2) > 0.$$

These follow from $U'(.) > 0$ and $U''(.) < 0$. **QED**

[22] The optimal sharing rule gives some insurance to both parties, for both are risk-averse. Appendix B proves this result under full information. The proof under hidden information runs similarly.

Show that $\frac{dc_y^2}{d\frac{p_{\bar{x}}}{p_{\underline{x}}+p_{\bar{x}}}} = -\frac{\left|\hat{\bar{H}}_{\frac{p_{\bar{x}}}{p_{\underline{x}}+p_{\bar{x}}}}\right|}{\left|\hat{\bar{H}}\right|} < 0$ **evaluated at** $\hat{\lambda}$ **and** $(\hat{c}_y^2, \hat{c}_x^2)$**.**

$$\left|\hat{\bar{H}}_{\frac{p_{\bar{x}}}{p_{\underline{x}}+p_{\bar{x}}}}\right| = (1-p_y)\, U^{2\prime}(c_x^2)\, p_y\, U^{2\prime}(c_y^2)\, \left[U^{1\prime}(w_{\underline{x}} - c_x^2) - U^{1\prime}(w_{\bar{x}} - c_x^2)\right] > 0$$

because $U'(.) >$, $U''(.) < 0$ and $w_{\underline{x}} < w_{\bar{x}}$, so that $\left[U^{1\prime}(w_{\underline{x}} - c_x^2) - U^{1\prime}(w_{\bar{x}} - c_x^2)\right] > 0$. **QED**

Show that $\left|\tilde{\bar{H}}\right| > 0$ **evaluated at** $\tilde{\lambda}$ **and** $(\tilde{c}_y^2, \tilde{c}_x^2)$**.**

$$\left|\tilde{\bar{H}}\right| = \begin{vmatrix} 0 & 0 & p_y\, U^{2\prime}(c_y^2) & (1-p_y)\, U^{2\prime}(c_x^2) \\ 0 & 0 & -1 & 0 \\ p_y\, U^{2\prime}(c_y^2) & -1 & h_{22} & 0 \\ (1-p_y)\, U^{2\prime}(c_x^2) & 0 & 0 & h_{33} \end{vmatrix} = \left[(1-p_y)\, U^{2\prime}(c_x^2)\right]^2 > 0,$$

where h_{22} and h_{33} are defined by (13) and (14), respectively. **QED**

Show that $\frac{dc_y^2}{d(k^2-k)} = -\frac{\left|\tilde{\bar{H}}_{(k^2-k)}\right|}{\left|\tilde{\bar{H}}\right|} = 1$ **evaluated at** $\tilde{\lambda}$ **and** $(\tilde{c}_y^2, \tilde{c}_x^2)$**.**

$$\left|\tilde{\bar{H}}_{(k^2-k)}\right| = -\left[(1-p_y)\, U^{2\prime}(c_x^2)\right]^2 < 0.$$ **QED**

Show that $\frac{dc_y^2}{dy} = -\frac{\left|\tilde{\bar{H}}_y\right|}{\left|\tilde{\bar{H}}\right|} = 1$ **evaluated at** $\tilde{\lambda}$ **and** $(\tilde{c}_y^2, \tilde{c}_x^2)$**.**

$$\left|\tilde{\bar{H}}_y\right| = -\left[(1-p_y)\, U^{2\prime}(c_x^2)\right]^2 < 0.$$ **QED**

Show that $\frac{dc_y^2}{dp_y} = \frac{dc_y^2}{d\underline{x}} = \frac{dc_y^2}{d\bar{x}} = \frac{dc_y^2}{d\frac{p_{\bar{x}}}{p_{\underline{x}}+p_{\bar{x}}}} = 0$ **evaluated at** $\tilde{\lambda}$ **and** $(\tilde{c}_y^2, \tilde{c}_x^2)$**.**

$$\left|\tilde{\bar{H}}_{p_y}\right| = \left|\tilde{\bar{H}}_{\underline{x}}\right| = \left|\tilde{\bar{H}}_{\bar{x}}\right| = \left|\tilde{\bar{H}}_{\frac{p_{\bar{x}}}{p_{\underline{x}}+p_{\bar{x}}}}\right| = 0.$$ **QED**

B Proof of proposition 2

The commenda contract solves the relevant optimization problem with $\theta = 1$ and $k^1 = 0$

Program 3:

$$\max_{\{c_s^2\}_{s\in S}} \quad E[U^1(w_s - c_s^2)]$$

$$\text{s.t.} \quad E[U^2(c_s^2)] = \overline{U}^2 \tag{19}$$

$$w_s - c_s^2 \geq 0 \;\forall s \tag{20}$$

$$c_s^2 \geq 0 \;\forall s. \tag{21}$$

Step 1. Show that all individually-rational efficient allocations are characterized by $c_y^2 < c_{\underline{x}}^2 < c_{\bar{x}}^2$.

Let η^2 and μ_s^1 be the Kuhn-Tucker multipliers of restrictions (19) and (20) for each s, respectively. Define the Lagrangian function for program 3 as

$$\pounds(c_s^2, \eta^2, \mu_s^1) = E[U^1(w_s - c_s^2)] + \eta^2(-\overline{U}^2 + E[U^2(c_s^2)]) + \sum_s \mu_s^1(w_s - c_s^2).$$

Program 3 is concave so that Kuhn-Tucker conditions are necessary and sufficient for optimality:

$$\frac{\partial \pounds(.)}{\partial c_s^2} = -p_s U^{1'}(w_s - c_s^2) + \eta^2 p_s U^{2'}(c_s^2) - \mu_s^1 \leq 0 \quad c_s^2 \geq 0 \quad c_s^2 \frac{\partial \pounds(.)}{\partial c_s^2} = 0 \quad \forall s$$

$$\frac{\partial \pounds(.)}{\partial \eta^2} = -\overline{U}^2 + E[U^2(c_s^2)] \geq 0 \qquad \eta^2 \geq 0 \quad \eta^2 \frac{\partial \pounds(.)}{\partial \eta^2} = 0 \tag{22}$$

$$\frac{\partial \pounds(.)}{\partial \mu_s^1} = w_s - c_s^2 \geq 0 \qquad \mu_s^1 \geq 0 \quad \mu_s^1 \frac{\partial \pounds(.)}{\partial \mu_s^1} = 0 \quad \forall s.$$

Let $c_s^2 > 0 \forall s$, then complementary slackness in (22) ensures that $\frac{\partial \pounds(.)}{\partial c_s^2} = 0$. Then, $c_y^2 < c_{\underline{x}}^2$ because

$$\text{if } \mu_y^1 = \mu_{\underline{x}}^1 = 0 \qquad \Psi(c_y^2, c_{\underline{x}}^2; \lambda_1) = \frac{U^{2'}(c_y^2)}{U^{2'}(c_{\underline{x}}^2)} - \frac{U^{1'}(w_y - c_y^2)}{U^{1'}(w_{\underline{x}} - c_{\underline{x}}^2)} = 0$$

$$\text{if } \mu_y^1 > 0 \text{ and } \mu_{\underline{x}}^1 = 0 \qquad \Psi(c_y^2, c_{\underline{x}}^2; \lambda_1) = \frac{U^{2'}(c_y^2)}{U^{2'}(c_{\underline{x}}^2)} - \frac{U^{1'}(w_y - c_y^2)}{U^{1'}(w_{\underline{x}} - c_{\underline{x}}^2)} > 0$$

$$\text{if } \mu_y^1 = 0 \text{ and } \mu_{\underline{x}}^1 > 0 \qquad c_{\underline{x}}^2 = w_{\underline{x}} > w_y \geq c_y^2.$$

$\Psi(c_y^2, c_{\underline{x}}^2; \lambda_1) = \frac{U^{2'}(c_y^2)}{U^{2'}(c_{\underline{x}}^2)} - \frac{U^{1'}(w_y - c_y^2)}{U^{1'}(w_{\underline{x}} - c_{\underline{x}}^2)} \geq 0$ derives from operating the Kuhn-Tucker conditions for $\mu_y^1 \geq 0$ and $\mu_{\underline{x}}^1 = 0$. From applying $U^{i'}(.) > 0$ and $U^{i''}(.) < 0$ to this expression, it follows that optimal event-contingent consumption must satisfy $c_y^2 < c_{\underline{x}}^2$. The equality $c_{\underline{x}}^2 = w_{\underline{x}}$ in the third expression derives from complementary slackness in (22) with $\mu_{\underline{x}}^1 > 0$; $w_{\underline{x}} > w_y$ by assumption; and $w_y \geq c_y^2$ is restriction (20) for $s = y$. Likewise, it can be proved that $c_{\underline{x}}^2 < c_{\bar{x}}^2$.

The case $c_y^2 = c_{\underline{x}}^2 = c_{\bar{x}}^2 = 0$ lies in the contract curve, but does not satisfy the participation constraint of agent 2. The case $c_s^2 = 0$ and $c_{s'}^2 > 0$ for $s, s' \in S$ and $s > s'$ leads to contradiction.

Step 2. Show that all individually-rational efficient allocations are characterized by

$$c_y^2 = w_y = k^2 - k + y.$$

Assume they are not and, then, let $(k^2 - k + \hat{t_y}, k^2 - k + \hat{t_{\underline{x}}}, k^2 - k + \hat{t_{\bar{x}}})$ be the solution of program 2, with $\hat{t_y} \neq y$. From imposing non-negative consumption, it follows that $\hat{t_y} < y$ and it is possible to write

$$\hat{t_{\underline{x}}} = \underline{a} + d$$

$$\hat{t_{\bar{x}}} = \bar{a} + d$$

with $\bar{a} \neq 0 \neq \underline{a}$, $E(a) = 0$ and $d = \frac{p_{\bar{x}}}{p_{\underline{x}} + p_{\bar{x}}} \hat{t_{\bar{x}}} + \frac{p_{\underline{x}}}{p_{\underline{x}} + p_{\bar{x}}} \hat{t_{\underline{x}}}$. For notational purposes, let us define $E[u^1(\tau_y, \tau_{\underline{x}}, \tau_{\bar{x}})] = E[U^1(s - \tau_s)]$ and $E[u^2(\tau_y, \tau_{\underline{x}}, \tau_{\bar{x}})] = E[U^2(k^2 - k + \tau_s)]$.

Let the event-contingent allocation $(k^2 - k + y, k^2 - k + \tilde{t_x}, k^2 - k + \tilde{t_x})$ be the solution to program 2. Then, for $d \neq \tilde{t_x}$, it holds that if

$$E[u^2(\hat{t_y}, d, d)] \geq E[u^2(y, \tilde{t_x}, \tilde{t_x})] = \overline{U}^2,$$

$$E[u^1(\hat{t_y}, d, d)] < E[u^1(y, \tilde{t_x}, \tilde{t_x})].$$

Let also define $(k^2 - k + y, k^2 - k + \tilde{t_{\underline{x}}}, k^2 - k + \tilde{t_{\bar{x}}})$ as the solution to a restricted version of program 3 in the sense that $c_y^2 = k^2 - k + y$ is imposed. If $(k^2 - k + \hat{t_y}, k^2 - k + \hat{t_{\underline{x}}}, k^2 - k + \hat{t_{\bar{x}}})$ is efficient, then, by definition,

$$E[u^2(\hat{t_y}, \underline{a} + d, \bar{a} + d)] = \overline{U}^2 = E[u^2(y, \tilde{t_x}, \tilde{t_x})] \tag{23}$$

$$E[u^1(\hat{t_y}, \underline{a} + d, \bar{a} + d)] > E[u^1(y, \tilde{t_{\underline{x}}}, \tilde{t_{\bar{x}}})]. \tag{24}$$

It can be proved that (24) leads to a contradiction and, therefore, the optimal allocation of consumption establishes $c_y^2 = k^2 - k + y$. Indeed,

$$E[u^1(\hat{t_y}, \underline{a} + d, \bar{a} + d)] < E[u^1(\hat{t_y}, d, d)] < E[u^1(y, \tilde{t_x}, \tilde{t_x})] < E[u^1(y, \tilde{t_{\underline{x}}}, \tilde{t_{\bar{x}}})], \tag{25}$$

where the first inequality derives from the utility function being concave and $E(a) = 0$. The second one follows from $(k^2 - k + y, k^2 - k + \tilde{t_x}, k^2 - k + \tilde{t_x})$ solving program 1 and from

$$E[u^2(\hat{t_y}, d, d)] > E[u^2(\hat{t_y}, \underline{a} + d, \bar{a} + d)] = \overline{U}^2 = E[u^2(y, \tilde{t_x}, \tilde{t_x})],$$

where the inequality derives from the utility function being concave and $E(a) = 0$ and the equalities are imposed by (23). The last inequality of (25) holds because the allocation $(k^2 - k + y, k^2 - k + \tilde{t_x}, k^2 - k + \tilde{t_x})$ could have been chosen—program 2 is a restricted version of program 3— but it was not. Therefore, it must give less expected utility to agent 1 than the optimally chosen allocation $(k^2 - k + y, k^2 - k + \tilde{t_{\underline{x}}}, k^2 - k + \tilde{t_{\bar{x}}})$.

Step 3. The individually-rational efficient allocations of consumption

$$(k^2 - k + y, k^2 - k + \tilde{t_{\underline{x}}}, k^2 - k + \tilde{t_{\bar{x}}})$$

can be sustained by a commenda contract establishing $\tau = -k$, $\tau_y = y$, $\tau_{\underline{x}} = \tilde{t_{\underline{x}}}$, and $\tau_{\bar{x}} = \tilde{t_{\bar{x}}}$. Just note that contracts are defined such that $c_s^2 = k^2 + \tau + \tau_s$. **QED**

C Proof of proposition 3 and lemma 1

The relevant problem when the merchant is initially endowed to fund the venture on his own $(k^1 > k)$ becomes a restricted version of program 2 (under hidden information, $\theta = 0$) or program 3 (under full information, $\theta = 1$) in which restriction (5) is added. The proof is developed for the hidden information structure ($\theta = 0$), but can be extended to full information ($\theta = 1$) easily.

<u>Step 1:</u> Show that $c_y^{2*} > k^2 - k + y$.

When the entrepreneur lacks the wealth to finance his project in its entirety ($k^1 = 0$), subsection 2.2.1, and proposition 1 in particular, staters the conditions under which the optimal allocation is a binding solution with a positive Kuhn-Tucker multiplier μ_y^1 associated with the restriction $w_y - c_y^2 \geq 0$. This means that for the (binding) solution $(\tilde{c_y^2}, \tilde{c_x^2})$,

$$\Upsilon(\tilde{c_y^2}, \varphi(\tilde{c_y^2}, \lambda_1); \lambda_1) > 0, \tag{26}$$

where $\tilde{c_y^2} = k^2 - k + y$ and $\tilde{c_x^2} = k^2 - k + \tilde{t_x}$, and λ_1 represents parameter values representing a risky and costly venture, and $\theta = 0$, $k^1 = 0$.

From (26) and utility functions exhibiting DARA, it follows that the allocation $(\tilde{c_y^2}, \tilde{c_x^2})$ is not optimal for parameters λ_2 such that $k^1 > k$ either.

Lemma 2 $\Upsilon(\tilde{c_y^2}, \tilde{c_x^2}; \lambda_2) > 0.$

<u>Proof of Lemma 2:</u> $\Upsilon(\tilde{c_y^2}, \tilde{c_x^2}; \lambda_1) > 0$, and

$$\frac{\partial \Upsilon(c_y^2, c_x^2; \lambda)}{\partial k^1} = -\frac{U^{1''}(w_y - c_y^2)[p\,U^{1'}(w_{\bar{x}} - c_x^2) + (1-p)U^{1'}(w_{\underline{x}} - c_x^2)]}{[p\,U^{1'}(w_{\bar{x}} - c_x^2) + (1-p)U^{1'}(w_{\underline{x}} - c_x^2)]^2} + \frac{U^{1'}(w_y - c_y^2)[p\,U^{1''}(w_{\bar{x}} - c_x^2) + (1-p)U^{1''}(w_{\underline{x}} - c_x^2)]}{[p\,U^{1'}(w_{\bar{x}} - c_x^2) + (1-p)U^{1'}(w_{\underline{x}} - c_x^2)]^2}$$

$$= \frac{R^1(w_y - c_y^2)\,U^{1'}(w_y - c_y^2)}{[p\,U^{1'}(w_{\bar{x}} - c_x^2) + (1-p)U^{1'}(w_{\underline{x}} - c_x^2)]} - \frac{R^1(w_x - c_x^2)\,U^{1'}(w_y - c_y^2)}{[p\,U^{1'}(w_{\bar{x}} - c_x^2) + (1-p)U^{1'}(w_{\underline{x}} - c_x^2)]} =$$

$$= \frac{U^{1'}(w_y - c_y^2)}{[p\,U^{1'}(w_{\bar{x}} - c_x^2) + (1-p)U^{1'}(w_{\underline{x}} - c_x^2)]}\left[R^1(w_y - c_y^2) \; - \; R^1(w_x - c_x^2)\right] > 0,$$

where the first equality derives from simple derivation; the second one from applying the definition of absolute risk-aversion coefficient, $R(z) = -\frac{U''(z)}{U'(z)}$, and (15); the third equality derives from operating and the inequality from $U'(.) > 0$, $U''(.) < 0$ and the utility function exhibiting DARA, with $w_y - c_y^2 < w_{\underline{x}} - c_x^2 < w_x - c_x^2$, so that $R^1(w_y - c_y^2) > R^1(w_x - c_x^2)$.**QED**

Therefore, the optimal allocation is not $(\tilde{c_y^2}, \tilde{c_x^2})$ but $(c_y^{2*}, c_x^{2*}) = (\tilde{c_y^2} + \epsilon, \tilde{c_x^2} - \delta(\epsilon))$, where different values of ϵ define distinct points in the core.

Lemma 3 *There exists an $\epsilon > 0$ and a $\delta(\epsilon) > 0$ such that all the restrictions are satisfied and $\Upsilon(\tilde{c_y^2} + \epsilon, \tilde{c_x^2} - \delta(\epsilon); \lambda_2) = 0$.*

Proof of Lemma 3: The result follows from applying the sign of the following derivatives to lemma 2. $\frac{\partial\Upsilon(c_y^2,c_x^2;\lambda)}{\partial c_y^2} < 0$ and $\frac{\partial\Upsilon(c_y^2,c_x^2;\lambda)}{\partial c_x^2} > 0$. The proof is straightforward. Just find the derivatives and note that $U'(.) > 0$ and $U''(.) < 0$. **QED**

Lemma 4 *The contract curve for interior points, defined by $\varphi(c_y^2, \lambda)$ for parameters λ_2, such that $k^1 > k > 0$, lies below the contract curve for λ_1, with $k^1 = 0$: $\varphi(c_y^2, \lambda_2) < \varphi(c_y^2, \lambda_1)\ \forall c_y^2$.*

Proof of Lemma 4: The *Implicit Function Theorem* also gives the first-order comparative statics of any parameter on $\varphi(c_y^2)$, for any c_y^2 at a solution. In particular,

$$\frac{d\,\varphi(c_y^2,\lambda)}{d\,k^1} = -\frac{\frac{\partial\Upsilon(c_y^2,c_x^2;\lambda)}{\partial k^1}}{\frac{\partial\Upsilon(c_y^2,c_x^2;\lambda)}{\partial c_x^2}} < 0\ \forall c_y^2 \text{ in the restricted set,} \tag{27}$$

since $U'(.) > 0$, $U''(.) < 0$ and the utility functions exhibit decreasing absolute risk-aversion (DARA). **QED**

Therefore, the optimal allocation establishes $c_y^{2*} = k^2 - k + y + \epsilon$ with $\epsilon > 0$.

Step 2: Show that $c_y^{2*} < k^2$.

This follows from imposing the optimal sharing rule $c_y^{2*} < c_x^{2*}$ to the ex-ante participation constraint of agent 1 holding with equality and noting that all individually rational allocations of agent 2's consumption are upper-bounded by the ex- ante participation constraint of agent 1.

Let $c_y^1 = w_y - c_y^2 \leq k^1 - k + y$, and, consequently, $c_y^2 \geq (k^1 + k^2 - k + y) - k^1 + k - y = k^2$. Then, for $E[U^1(w_s - c_s^2)] = E[U^1(k^1 - k + s)]$ to be satisfied, $c_{\bar{x}}^1 = w_{\bar{x}} - c_x^2 > k^1 - k + \bar{x}$. These, in turn, imply that $c_x^2 \leq k^2$, which is in contradiction with the optimal sharing rule, $c_y^{2*} < c_x^{2*}$.

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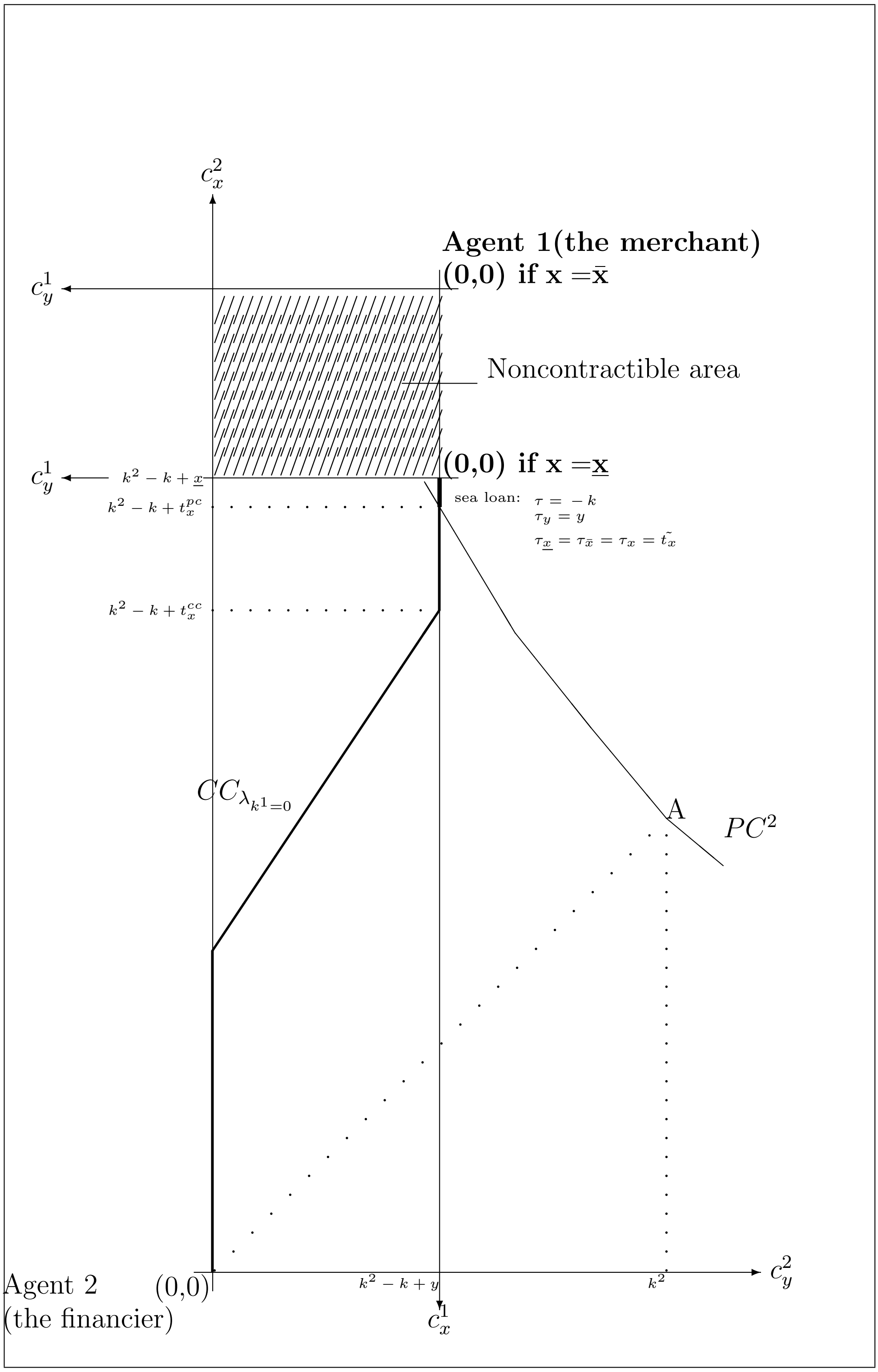
FIGURE I ($k^1 = 0$)



c_x^2
Agent 1(the merchant)
(0,0) if x =x̄
c_y^1
Noncontractible area
(0,0) if x =x
c_y^1
$k^2 - k + \underline{x}$
$k^2 - k + t_x^{pc}$
sea loan: $\tau = -k$
$\tau_y = y$
$\tau_{\underline{x}} = \tau_{\bar{x}} = \tau_x = \tilde{t_x}$
$k^2 - k + t_x^{cc}$
$CC_{\lambda_{k^1=0}}$
A
PC^2
Agent 2
(the financier)
(0,0)
$k^2 - k + y$
k^2
c_y^2
c_x^1

FIGURE II ($k^1 = 0$)

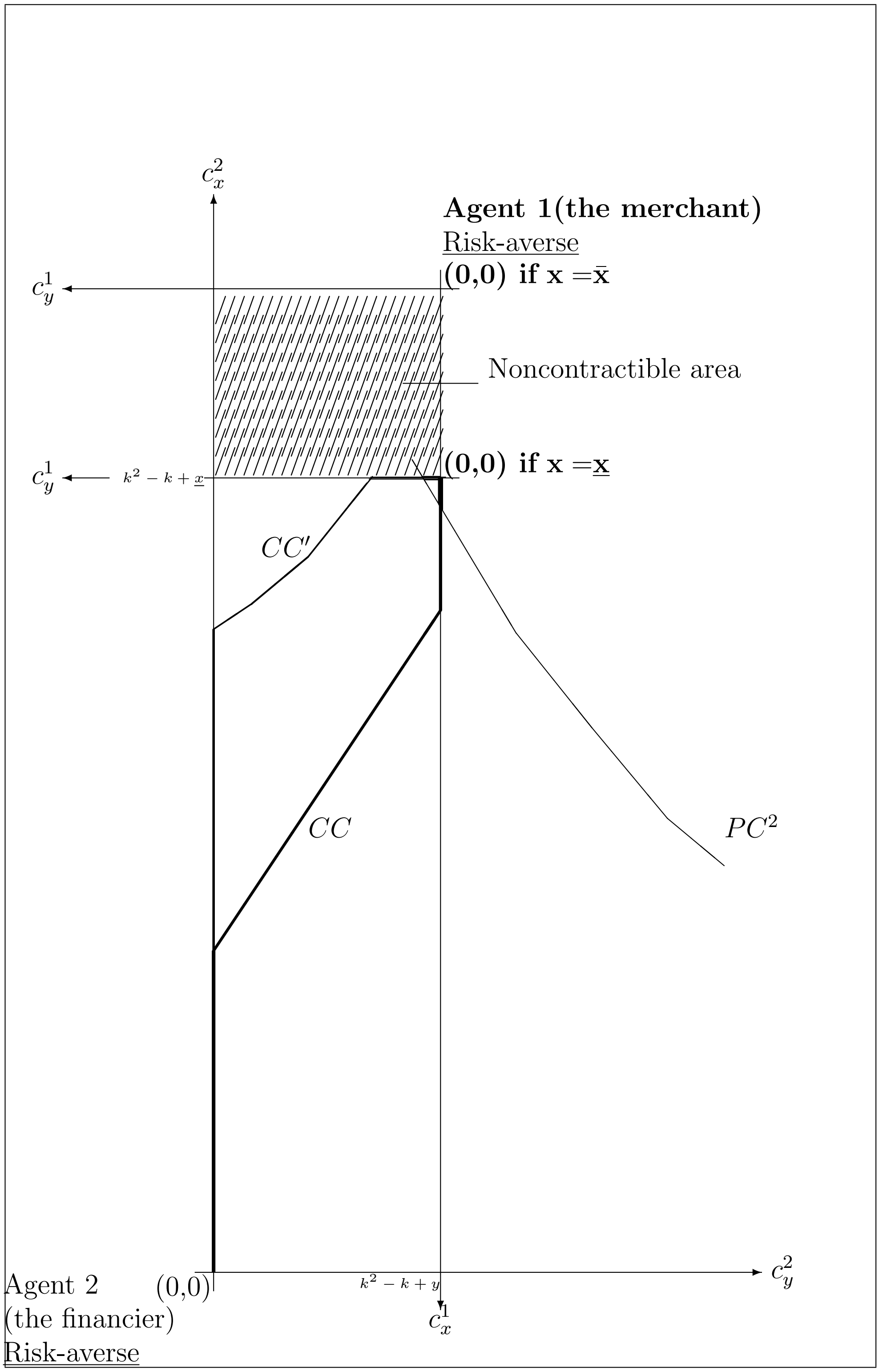


FIGURE III

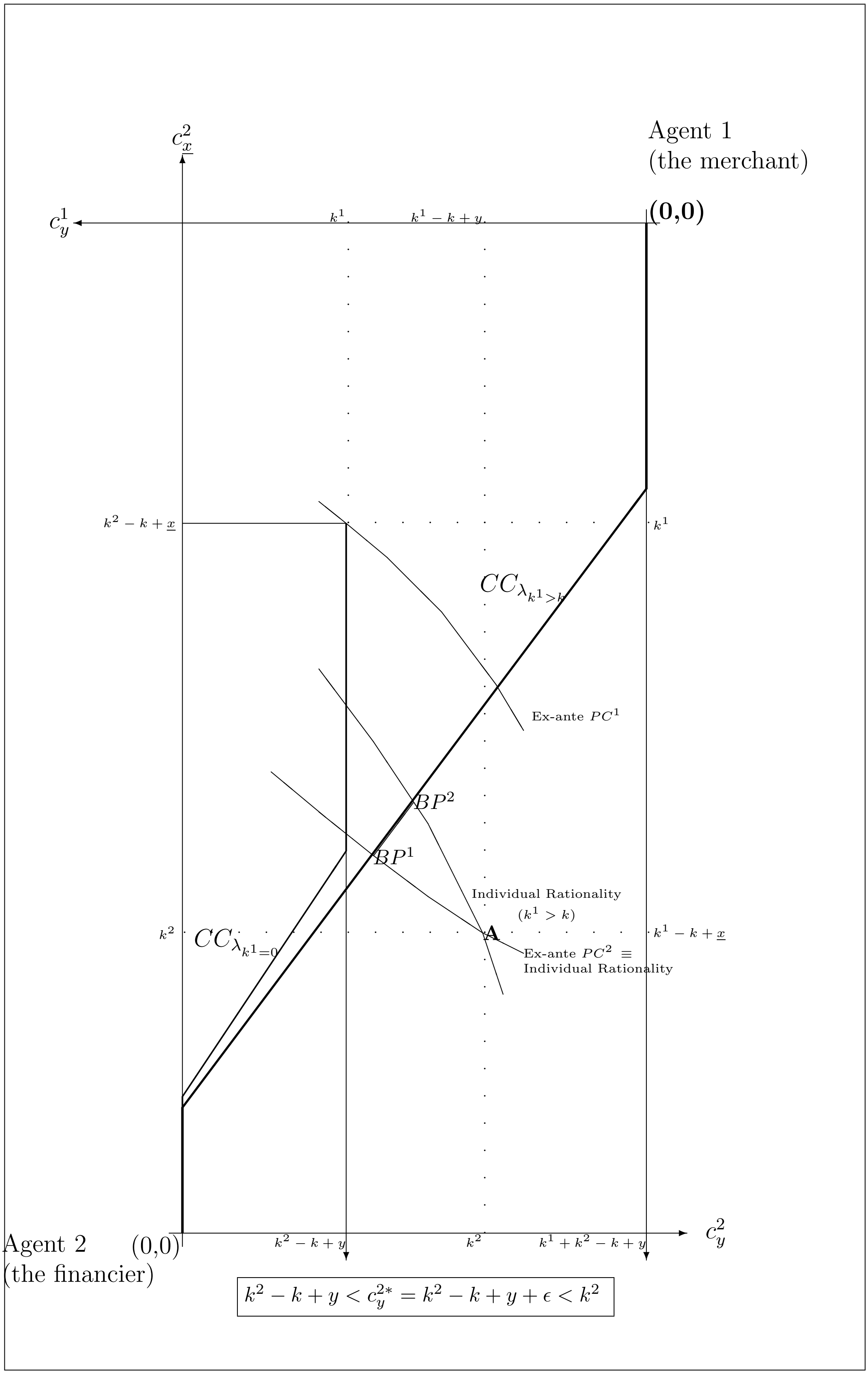
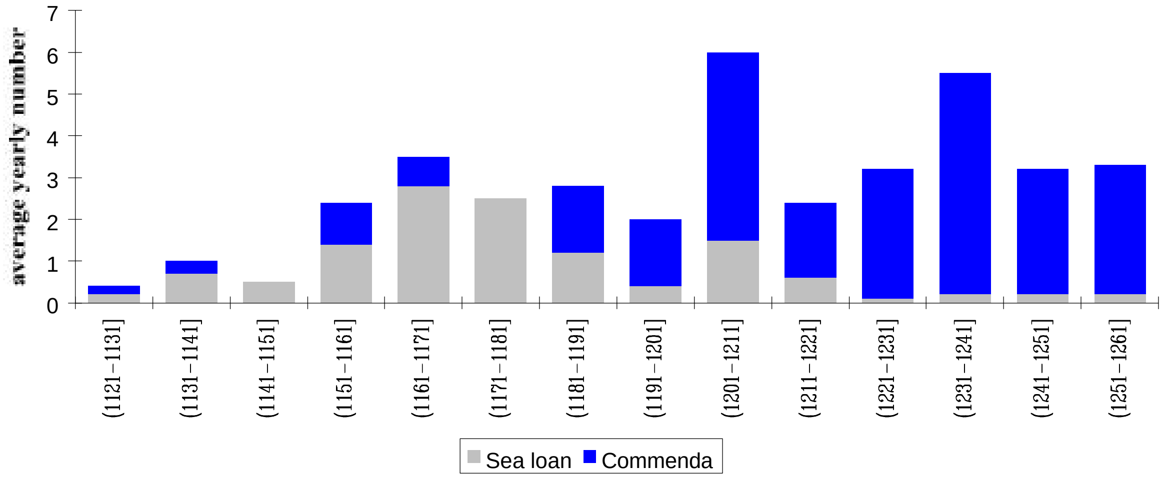

Agent 1
(the merchant)
(0,0)
$c_{\underline{x}}^2$
c_y^1
k^1
$k^1 - k + y$
$k^2 - k + \underline{x}$
k^1
$CC_{\lambda_{k^1>k}}$
Ex-ante PC^1
BP^2
BP^1
Individual Rationality
$(k^1 > k)$
k^2
$CC_{\lambda_{k^1=0}}$
A
$k^1 - k + \underline{x}$
Ex-ante $PC^2 \equiv$
Individual Rationality
Agent 2
(the financier)
(0,0)
$k^2 - k + y$
k^2
$k^1 + k^2 - k + y$
c_y^2
$k^2 - k + y < c_y^{2*} = k^2 - k + y + \epsilon < k^2$

FIGURE IV


average yearly number
7
6
5
4
3
2
1
0
(1121–1131]
(1131–1141]
(1141–1151]
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(1201–1211]
(1211–1221]
(1221–1231]
(1231–1241]
(1241–1251]
(1251–1261]
Sea loan
Commenda