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RESEARCH ARTICLE

Costly state verification and truthtelling: a note on the theory of debt contracts

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Abstract When firms want to raise external financing, why do they resort to contracts with fixed repayment, i.e., standard debt contracts? The canonical work of Gale and Hellwig (Rev Econ Stud, 52(4):647–663, 1985) gives the following answer to this question: Assuming that only the entrepreneur can observe the project's outcome free of charge, the standard debt contract proves to be an incentive-compatible financing design. However, this approach remains inadequate, as neither the lender nor the borrower is given the possibility to act strategically. The paper at hand takes up this aspect. By means of a simple game-theoretic model and focusing on a binary outcome setting, it is shown that every risky standard debt contract is dominated by at least one ownership contract. In this respect, costly state verification cannot act as a raison d'être of contracts with fixed repayment.

Keywords Costly state verification · Financing contracts · Incentive compatibility · Perfect Bayesian Nash equilibrium

JEL Classification C72 · D82 · D86 · G32

1 Introduction

When firms want to raise external financing, why do they resort to contracts with fixed repayment, i.e., standard debt contracts? A common feature underlying the explanations to be found in the relevant literature is some kind of ex post information asymmetry: The entrepreneur can divert (parts of) the income at the expense of the

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investor, a threat largely mitigated if debt contracts are agreed upon. The models provided differ in the form of diversion, more precisely the extent to which verifiability of income is assumed. Innes (1990) analyzes the case of fully verifiable income. It is shown that standard debt contracts exhibit superior incentive properties if managerial effort increases the project's cash flow. This is due to the fact that the entrepreneur (borrower) serves as a "residual claimant" for marginal cash flows above the fixed repayment level. At the other extreme, no verification is possible. In this context, motivation for compliance can result from a threat to withhold future financing (Bolton and Scharfstein 1990, 1996) or to foreclose the entrepreneur's assets (Hart and Moore 1998) if a fixed repayment obligation is not met.

The class of costly state verification models lies somewhere between the two polar cases. Subsequent to the signing of the contract and the project's execution, one party can observe the realized state without any difficulty, whereas the other has to bear costs of verifying the state.[1] The first formal analysis of this constellation, dedicated to a generalized product market, is to be found in the paper of Townsend (1979). A positive theory of debt contracts has been developed by the highly cited work of Gale and Hellwig (1985). Assuming that only the entrepreneur can observe the project's outcome free of charge, the standard debt contract proves to be an incentive-compatible arrangement. Here, incentive compatibility implies that the entrepreneur reveals his/her information truthfully. The costly state verification approach according to Townsend (1979) and Gale and Hellwig (1985) has been extended in a number of ways. We simply make brief mention of the work of Diamond (1984) concerning delegated monitoring, which had a serious impact on the theory of financial intermediation, the investigation of stochastic auditing conducted by Mookherjee and Png (1989), and the examination of multilateral contracts undertaken by Krasa and Villamil (1994). Recently, the results of Gale and Hellwig (1985) mainly serve as a stepping stone to more comprehensive models. Examples include the papers of Grenadier and Malenko (2011), De Fiore and Tristani (2013), and Carlstrom et al. (2016). Common to these papers is the restriction to truthtelling contracts. As to the analysis of Gale and Hellwig (1985), this presumption implies that neither the lender nor the borrower is allowed to act strategically[2], i.e., in an interactive way.

The paper at hand takes up this shortcoming and analyzes the behavior of investor and entrepreneur in a perfect Bayesian Nash equilibrium. It thus follows the approach of Krasa and Villamil (2000)[3], yet departs in two ways. First, we focus on a binary outcome setting. Second, the entrepreneur faces an exogenously given cost if misreporting is detected. Comparable inspection games are to be found in the areas of auditing (e.g., Lu and Sapra 2009) and tax compliance (Andreoni et al. 1998). Bester (1994) and Neus and Stadler (2013) argue, to some extent, along parallel lines, but concentrate on the effects of collateral and do not compare different contract designs. Further, Gale and Hellwig (1985) (likewise Krasa and Villamil 2000) endogenously derive the optimal contract. In contrast, we assume given contract functions. This is

[1] Occasionally, this is called a situation of "semiverifiable" results, cf. Tirole (2006), pp. 131 and 138.

[2] Our understanding of strategic behavior coincides with the work of Dixit and Nalebuff (1991).

[3] Extensions of this model are provided by Krasa et al. (2005, 2008).

justifiable in the light of our main result: The presence of penalties casts doubts on whether costly state verification can be said to explain the existence of debt contracts. Within the framework developed, every risky standard debt contract is Pareto dominated by at least one ownership contract. Numerical calculations with more than two possible outcomes reproduce this ordering for high levels of external financing.

The remainder of the paper progresses as follows: Section 2 introduces the problem formulation. In Sect. 3, we present our game-theoretic model. Implications for the optimality of financing contracts are to be found in Sect. 4, while Sect. 5 undertakes a numerical extension to multiple states. Section 6 concludes the paper.

2 The problem

The entrepreneur is endowed with a (profitable) project. For simplicity's sake, we assume that the outcome of the project can take on only two values at the end of the period. If the project is successful, it yields a cash flow of x_1, otherwise the outcome is x_2, where $x_1 > x_2 > 0$ applies. The relevant agents are assumed to exhibit risk-neutral behavior (or maximize market value of their claims under risk-neutral probabilities). They agree on the probabilities p (for x_1) and $1 - p$ (for x_2). The risk-neutral discount rate is supposed to equal zero for mathematical convenience and without loss of generality. The entrepreneur has no liquid funds, but wants to consume now and is looking for an investor to (partly) finance the project. Two contract designs are considered. These are

(i) a fixed repayment in the amount of D (standard debt contract) as well as
(ii) a variable claim with a positive share α of the cash flow (ownership structure).

The cash flow in favor of the presumed investor depends on the realized event, the entrepreneur's report, and the audit strategy chosen by the investor. For concreteness, the following is assumed:

1. The realized outcome is only observable to the entrepreneur, whereas the external investor has to incur constant costs $c \geq 0$ to monitor the project's cash flow.[4]
2. Where there is no audit, the contract specifies a repayment $s(r)$ contingent on the reported cash flow r.
3. Where there is an audit, the contractual repayment $s(x)$ depends on the realized cash flow x.
4. The contract functions mentioned satisfy $s(x) = \alpha \cdot x$ (ownership structure) and $s(x) = \min(x, D)$ (standard debt contract with repayment promise D and limited liability).
5. If misreporting is detected, a (non-pecuniary) penalty $z \geq 0$ is imposed on the entrepreneur.[5]

[4] In reality, inspection costs may depend on the true cash flow. Yet, in the context of our model, this would not provide further insights.

[5] Non-pecuniary penalties such as imprisonment or loss of reputation exhibit monetary equivalents to the entrepreneur, but no utility to the investor (cf. Diamond 1984, p. 396). In cases where the penalty z (partially) benefits the investor, our results continue to hold in a slightly weakened manner.

Under these terms, the choice of a financing contract is driven largely by the objective of minimizing inspection costs. To exclude the trivial case of riskless financing (i.e., $s(x_1) = s(x_2)$), the financing required is assumed to exceed x_2.

Gale and Hellwig (1985) devise an incentive-compatible financing design as follows:[6] The contract separates all conceivable reports on the realized states into two subsets. In the first subset, the investor always audits, whereas in the second subset, there is no inspection. The commitment to this audit strategy constitutes an enforcement mechanism that induces the entrepreneur to report truthfully. However, the framework of Gale and Hellwig (1985) remains inadequate. It rests upon the revelation principle developed in the mechanism design literature.[7] According to this tenet, the better-informed contracting party has an incentive to transmit its information truthfully if the recipient is able to credibly commit as to how the information will be used. That means, in the case where the entrepreneur expects the audit to take place as stated, he will always report the realized cash flow honestly. But if truthtelling is foreseen, once the report has been submitted, it is irrational to actually carry out the inspection. Conversely, the entrepreneur will anticipate this "empty threat". Hence, the model of Gale and Hellwig (1985) neglects the fact that the relationship between investor and entrepreneur could be understood as some kind of strategic interaction. The lender may audit or may not. The borrower may attempt to cheat or may not. For both of them, the only sensible course of action is to be unpredictable. Consequently, in the next section, we develop a game-theoretic approach.

3 The game

Figure 1 illustrates this game, where we allow the players to adopt randomized moves, i.e., mixed strategies. To begin with, the contract is assumed to be given. In stage one, nature determines the project's cash flow. x_1 is realized with probability p and x_2 otherwise. In stage two, the successful entrepreneur reasons whether to correctly report the observed cash flow, i.e., $r = x_1$, or to cheat, i.e., $r = x_2$. In the first case, he/she obtains $x_1 - s(x_1)$. In the second case, his/her surplus depends on whether the investor audits ($x_1 - s(x_1) - z$) or not ($x_1 - s(x_2)$). We determine the probability of misreporting w, i.e., the entrepreneur's probability of reporting x_2 although x_1 has been realized. In stage three, the investor decides if the report $r = x_2$ received is to be believed. If so, he/she obtains the repayment $s(x_2)$. If not, he/she either gets $s(x_1) - c$ or $s(x_2) - c$, depending on the audited cash flow. We calculate the investor's probability of inspection v if the entrepreneur announces the unfavorable outcome. Due to the dynamic structure explicated, the appropriate solution concept for the game is the perfect Bayesian Nash equilibrium (cf. Fudenberg and Tirole 1991, Chap. IV).

[6] Textbook treatments are to be found in Bolton and Dewatripont (2005), pp. 190–198 and Tirole (2006), pp. 138–141.

[7] Cf. Myerson (1982).

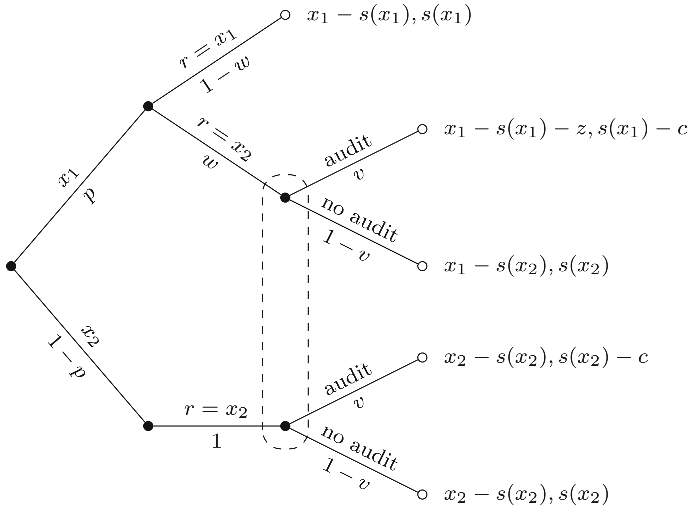

Fig. 1 Inspection game in extensive form

3.1 The audit decision of the investor

Initially, we are concerned with the audit decision of the investor assuming the entrepreneur's reporting strategy to be given (derivation of a best response). More precisely, the investor has to determine the probability of audit v provided that the entrepreneur cheats with probability w.

As the reasoning is straightforward, we only note that indifference between audit and non-audit prevails if

$$\hat{w} = \frac{1-p}{p} \cdot \frac{c}{s(x_1) - s(x_2) - c}$$

applies. In the following, $\hat{w}$ should be referred to as the critical probability of misreporting. In response to this probability, the investor's probability of inspection can be arbitrarily fixed (i.e., $v \in [0, 1]$). Other things being equal, the critical probability of misreporting is the smaller the higher the difference between the contractual repayments in the "good" and the "bad" state. Moreover, the expected cash flow to the investor adds up to

$$E\left[C_I\right] = p \cdot s(x_1) + (1-p) \cdot s(x_2) - (1-p) \cdot \frac{c \cdot [s(x_1) - s(x_2)]}{s(x_1) - s(x_2) - c}. \qquad (1)$$

In a competitive capital market, the investor's expected cash flow corresponds to his/her financing contribution. It thus describes the amount of external financing available to the entrepreneur by means of the given contract.

3.2 The reporting decision of the entrepreneur

In the next step, we analyze the entrepreneur's strategy development. He/she has to decide on the probability w of concealing the outcome x_1 assuming the investor audits with probability v.

For reasons of brevity, we confine ourselves to note that the entrepreneur is indifferent with regard to correct and knowingly false reporting if

$$\hat{v} = \frac{s(x_1) - s(x_2)}{s(x_1) - s(x_2) + z}$$

is provided. In response to the critical audit probability, the entrepreneur's probability of misreporting can be arbitrarily fixed (i.e., $w \in [0, 1]$). Other things being equal, $\hat{v}$ increases in line with the difference between the contractual repayments in the "good" and the "bad" state. Furthermore, we obtain

$$E\left[C_E\right] = p \cdot (x_1 - s(x_1)) + (1 - p) \cdot (x_2 - s(x_2)). \tag{2}$$

In the event that the investor implements the critical audit probability, the expected surplus of the entrepreneur matches the amount contractually agreed upon.

3.3 Equilibria

An equilibrium is characterized by mutually reassuring expectations concerning the probabilities. We can thus formulate the following proposition, where we have to distinguish six parameter regions.

Proposition 1 *1. For $c \geq s(x_1) - s(x_2)$ and $z \geq 0$, a pure strategy equilibrium with deterministic cheating (i.e., $w^* = 1$) and abstaining from audit (i.e., $v^* = 0$) emerges.*

2. *For $0 < c < s(x_1) - s(x_2), z \geq 0$ and $0 < p \leq \frac{c}{s(x_1)-s(x_2)}$, a pure strategy equilibrium with deterministic cheating (i.e., $w^* = 1$) and abstaining from audit (i.e., $v^* = 0$) emerges.*
3. *For $0 < c < s(x_1) - x(x_2), z = 0$ and $\frac{c}{s(x_1)-s(x_2)} < p < 1$, a pure strategy equilibrium with deterministic cheating (i.e., $w^* = 1$) and auditing (i.e., $v^* = 1$) emerges.*
4. *For $0 < c < s(x_1) - s(x_2), z > 0$ and $\frac{c}{s(x_1)-s(x_2)} < p < 1$, the combination*

$$v^* = \hat{v} = \frac{s(x_1) - s(x_2)}{s(x_1) - s(x_2) + z} \tag{3}$$

$$w^* = \hat{w} = \frac{1 - p}{p} \cdot \frac{c}{s(x_1) - s(x_2) - c} \tag{4}$$

is a mixed strategy equilibrium.

5. *For $c = 0$ and $z = 0$, a pure strategy equilibrium with deterministic cheating (i.e., $w^* = 1$) and auditing (i.e., $v^* = 1$) emerges.*

6. *For $c = 0$ and $z > 0$, a pure strategy equilibrium with deterministic truthtelling (i.e., $w^* = 0$) and auditing (i.e., $v^* = 1$) emerges.*

Proof Obviously, these values are mutually best responses. □

Below, we will concentrate on the parameter region characterized by moderate audit costs, a positive penalty, and a reasonable probability of success, i.e., the mixed strategy equilibrium according to Eqs. (3) and (4). The findings with regard to the remaining parameter regions are fairly intuitive and in line with the results of the subject-based literature. As is well-known since Krasa and Villamil (2000), costly state verification in the absence of penalties leads to deterministic auditing.

4 Optimality of the contract design

Based on the considerations so far, what can be said about the preferability of the financing contracts alluded to? In a perfect Bayesian Nash equilibrium, the expected cash flows to the contracting parties are given as Eqs. (1) and (2), respectively. The sum of both positions, referred to as the total market value, amounts to

$$E\left[C_E\right] + E\left[C_I\right] = p \cdot x_1 + (1-p) \cdot x_2 - (1-p) \cdot \frac{c \cdot [s(x_1) - s(x_2)]}{s(x_1) - s(x_2) - c}.$$

It describes the entrepreneur's position immediately prior to external financing, i.e., in consideration of the investor's financing contribution. Therefore, the expression

$$(1-p) \cdot \frac{c \cdot [s(x_1) - s(x_2)]}{s(x_1) - s(x_2) - c} \tag{5}$$

denotes the entrepreneur's drawback, i.e., the agency costs due to external financing as compared with internal financing.[8]

The supposed predominance of standard debt contracts cannot be maintained within the strategic context developed. To show this, Proposition 2 resorts to contracts that would raise funds in the same amount if there were no problem due to asymmetric information and the costs associated.

Proposition 2 *Every risky standard debt contract is Pareto-dominated by at least one ownership contract.*

Proof In the absence of asymmetric information, the financing contributions of debt contract and ownership structure (according to Eq. (1)) coincide if

$$p \cdot \alpha \cdot x_1 + (1-p) \cdot \alpha \cdot x_2 = p \cdot \min(x_1, D) + (1-p) \cdot \min(x_2, D)$$

[8] The level of penalty exerts no influence on the agency costs. Although the fine reduces the entrepreneur's surplus in the event that his/her misreporting has been detected, it coincides with a diminished audit probability of the investor. Comparable results have been deduced in political sciences, where the suitability of penalties for the purpose of crime prevention has been investigated, cf. Tsebelis (1990).

or

$$\alpha = \frac{p \cdot \min(x_1, D) + (1-p) \cdot \min(x_2, D)}{p \cdot x_1 + (1-p) \cdot x_2}$$

hold. In case of risky debt, i.e., $x_2 < D < x_1$, we obtain

$$\alpha = \frac{p \cdot D + (1-p) \cdot x_2}{p \cdot x_1 + (1-p) \cdot x_2}. \tag{6}$$

Using Eq. (6), simple calculations show that the agency costs of debt

$$(1-p) \cdot \frac{c \cdot [D - x_2]}{D - x_2 - c}$$

exceed the agency costs of the ownership structure

$$(1-p) \cdot \frac{c \cdot \alpha \cdot (x_1 - x_2)}{\alpha \cdot (x_1 - x_2) - c}$$

if, and only if,

$$c > 0$$

applies. Moreover, given Eq. (6), the expected cash flows to the entrepreneur (according to Eq. (2)) coincide even in the case of $c > 0$. Therefore, the higher efficiency loss associated with the debt contract affects the entrepreneur as a result of a lower financing contribution on the part of the investor. □

In our setting, the argument concerning audit costs, meaning costly state verification, cannot be invoked to explain the existence of standard debt contracts. On the contrary, it establishes the optimality of the ownership structure.

5 Numerical extension

The approach chosen in this paper does amount to something of a simplification by the very fact that the projects considered exhibit only two possible outcomes. An extension of the framework to multiple states seems desirable but ambitious, since universally valid analytical solutions cannot be obtained. Therefore, a numerical example is used to check the robustness of our main result to more than two states. The project's (high risk) cash flows are given as $x_1 = 350$, $x_2 = 250$, $x_3 = 150$, and $x_4 = 50$, respectively. The probabilities are assumed to equal one another, i.e., $p_1 = p_2 = p_3 = p_4 = 1/4$. Moreover, the costs of audit are specified to be $c = 5$. As to the penalty, we presume $z = 15$. We compare standard debt contract and ownership structure at three different levels of external financing. In each case, repayment promise D and ownership share α are chosen to assure that both contracts would raise funds in the same amount if symmetric information existed.

Table 1 Debt contract and ownership structure with multiple states

(a)		$D = 90$	$\alpha = 0.40$
Reporting	x_1 realized	(0, 0, 6/7, 1/7)	(1804/2415, 1/7, 1/15, 1/23)
strategy	x_2 realized	(0, 0, 1, 0)	(0, 1, 0, 0)
	x_3 realized	(0, 0, 1, 0)	(0, 0, 1, 0)
	x_4 realized	(0, 0, 0, 1)	(0, 0, 0, 1)
Audit	x_2 reported	(0, 1)	(8/11, 3/11)
strategy	x_3 reported	(0, 1)	(16/19, 3/19)
	x_4 reported	(8/11, 3/11)	(8/9, 1/9)
Expected	Entrepreneur	$E[C_E] = 120$	$E[C_E] = 120$
cash flows	Investor	$E[C_I] = 78.57$	$E[C_I] = 75.93$
(b)		$D = 180$	$\alpha = 0.70$
Reporting	x_1 realized	(0, 19/25, 1/5, 1/25)	(12400/14391, 1/13, 1/27, 1/41)
strategy	x_2 realized	(0, 1, 0, 0)	(0, 1, 0, 0)
	x_3 realized	(0, 0, 1, 0)	(0, 0, 1, 0)
	x_4 realized	(0, 0, 0, 1)	(0, 0, 0, 1)
Audit	x_2 reported	(0, 1)	(14/17, 3/17)
strategy	x_3 reported	(2/3, 1/3)	(28/31, 3/31)
	x_4 reported	(26/29, 3/29)	(14/15, 1/15)
Expected	Entrepreneur	$E[C_E] = 60$	$E[C_E] = 60$
cash flows	Investor	$E[C_I] = 137.20$	$E[C_I] = 136.08$
(c)		$D = 270$	$\alpha = 0.90$
Reporting	x_1 realized	(1780/2967, 1/3, 1/23, 1/43)	(28184/31535, 1/17, 1/35, 1/53)
Strategy	x_2 realized	(0, 1, 0, 0)	(0, 1, 0, 0)
	x_3 realized	(0, 0, 1, 0)	(0, 0, 1, 0)
	x_4 realized	(0, 0, 0, 1)	(0, 0, 0, 1)
Audit	x_2 reported	(4/7, 3/7)	(6/7, 1/7)
strategy	x_3 reported	(8/9, 1/9)	(12/13, 1/13)
	x_4 reported	(44/47, 3/47)	(18/19, 1/19)
Expected	Entrepreneur	$E[C_E] = 20$	$E[C_E] = 20$
cash flows	Investor	$E[C_I] = 175.75$	$E[C_I] = 176.12$

Note: The table shows the entrepreneur's reporting strategy (i.e., the probabilities for the possible reports) as a function of the realized cash flow, the investor's audit strategy (i.e., the probabilities for "audit" and "no audit") subject to the received report, and the expected cash flows to both players in perfect Bayesian Nash equilibrium

As a consequence of the enlarged state space, the players' strategy sets are more comprehensive. In stage one of the game, nature again determines the project's cash flow. In stage two, the entrepreneur is asked to report his/her observation. In general, this decision is no longer binary. That means, besides compliance, i.e., truthtelling, various forms of cheating, i.e., different degrees of misreporting, are possible. In stage three, the investor decides on the audit probabilities if less preferable reports have been received.

Table 1 shows the calculated equilibria, obtained with Game Theory Explorer (Savani and von Stengel 2015). Irrespective of the level of external financing, the entrepreneur's position in both debt contract and ownership structure is identical. However, there are differences concerning the financing contribution. With low levels of external financing, repaying the entire cash flow in the least preferable state is efficient, because it reduces the set of states underlying an audit (as described by Gale and Hellwig 1985). Consequently, debt financing dominates. With intermediate levels of external financing, the agency costs associated with both contract designs converge. Ultimately, with high levels of external financing (or congruence with respect to the audit subset), the ownership structure enables larger amounts of capital to be acquired. In contrast to Krasa and Villamil (2000), our model does not imply a sharp cut-off rule concerning the audit strategy. Rather, it predicts that the highest possible reports (or reports linked to the repayment contractually agreed upon) will not be audited and that, starting in the middle of the reporting range, the audit probability will increase as reported cash flow falls. Further numerical calculations show that our results are robust against changes in audit costs, penalties, probabilities or the loss given default.

6 Conclusions

Costly state verification according to Gale and Hellwig (1985) is commonly seen to provide for an economic justification of standard debt contracts. Yet, our paper shows that this reasoning is not robust against modifications in the underlying assumptions. Following Krasa and Villamil (2000), we rely on the idea that the relationship between investor and entrepreneur can be understood as some kind of strategic interaction. However, the model proposed in this article differs from Krasa and Villamil (2000) twofold. On the one hand, there are only two states of nature. On the other hand, the entrepreneur will be penalized if misreporting is detected. These conditions are shown to involve playing of mixed strategies and to establish the superiority of the ownership structure. A numerical analysis shows that, for high levels of external financing, the results extend to richer outcome distributions.

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