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Debt and equity as optimal contracts

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Abstract

This paper shows the simultaneous optimality of debt and equity contracts in a principal-agent model. The agent (an entrepreneur) has an investment project but does not have the necessary funds to finance it. There is moral hazard in the model, generated by the dependence of the project's expected return on the (unobservable) agent's effort. Key to the optimality of these financial instruments is the nonassignable rent produced by the project and captured by the entrepreneur when the investment is successful. © 1997 Elsevier Science B.V.

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1. Introduction

The security design literature has made important progress developing models in which debt is an optimal contract. Some have used a costly state verification argument, as in Townsend (1979), Diamond (1984), Gale and Hellwig (1985), and Hart and Moore (1989); others have used an adverse selection argument, as in Allen and Gale (1992). Important progress has also been made developing models in which equity is an optimal contract. Here, the most frequent explanation has been based on corporate control issues, as in Grossman and Hart (1988) and Harris and Raviv (1988).

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Some of these models-particularly those that show the optimality of debt using a costly state verification argument-have become very popular for studying a wide range of issues related to both banking and the financing of firms. However, the lack of an identical model in which both debt and equity are optimal contracts has made it difficult to address other issues, such as the separation of banking and commerce or the implications of the various regulations that limit banks' investments in the equity of nonfinancial firms. These questions have become more pertinent with both the advent of universal banking structures in the European Community countries and the ongoing discussion about repealing the Glass-Steagall Act in the United States.

A few studies attempted to derive the simultaneous optimality of debt and equity contracts, such as Chang (1987) and Williams (1989), but they are not without problems. Both use the same idea as Townsend (1979): Contracts cannot depend directly on the value of the firm's assets. But they also assume the existence in the firm of an asset or part of its return that can be allocated to outsiders through a contract. Chang adopts a model in which part of the investment's outcome is observable by everyone, while the other part is observable at no cost only by the firm's manager. Investors–debtholders and equityholders-can verify this part only at a cost. Williams uses a model in which the investment produces an outcome that is observable only by the firm's manager, who then reports it to outside investors. In addition, Williams assumes that the project produces a private benefit that increases strictly with the investment's outcome. This benefit is captured by the manager, but only if he is in control of the firm, that is, if he owns a certain fraction of the firm at the time the investment is realized. The optimal contracts derived in both papers have some similarities with a combination of debt and equity contracts, but the correspondence is not perfect. For example, in Chang's paper, the manager, rather than the equityholders, is the residual claimant of the firm. The problem in Williams' model is that the face value of debt that he uses to compute the payment to equityholders is different from the payment made to debtholders.

Bester and Hellwig (1987) show the optimality of debt and equity contracts in a principal-agent model by making use of the result that if the investment's output is determined by two variables that are controlled by the agent, then, in general, it is possible to implement the second-best outcome through a combination of two financial instruments.

The present paper develops a principal-agent model featuring the simultaneous optimality of debt and equity contracts regardless of the number of variables controlled by the agent [1]. In this model, the agent has an investment project, but does not have the necessary funds to finance it. The moral hazard is generated by

[1] For a study of some banking regulations using the framework presented in this paper, see Santos (1995).

the dependence of the investment's expected return on the (unobservable) agent's effort. Key to the simultaneous optimality of these financial instruments is the existence of a nonassignable rent produced by the project and captured by the agent if the project is successful. Such rent can be interpreted, for example, as the enhancement of the agent's reputation due to the project's success, which he can then report in order to obtain funding for other projects. It can also be interpreted, in accordance with Diamond (1991), as the benefit obtained by the agent for being in control of the firm.

The paper proceeds as follows: The model is introduced in Section 2. In Sections 3 and 4, respectively, the optimal contract is determined, and the optimality of debt and equity contracts is shown, together with some comparative static results. Final remarks are presented in Section 5, followed by Appendix A containing the proofs.

2. The model

In the principal-agent model presented here, there is an entrepreneur, the agent, who has an investment project but does not have the necessary funds to finance it. As a result, he must obtain these funds from a financier, the principal. The project produces an outcome that is observable at no cost, and a nonassignable rent that is captured by the entrepreneur, but only if the project is successful. Moral hazard in the model is generated by the dependence of the project's expected return on the (unobservable) agent's effort.

The assumptions of the model are as follows:

Assumption 1. The entrepreneur and the financier are both risk neutral. The entrepreneur has no funds, while the opportunity cost of the financier's capital, s, is exogenous to the model.

Assumption 2. The project requires an initial investment equal to $\bar{I}$, and produces one period later the outcome y_i with the probability p_i, $\forall i \in \{0, 1, 2, \ldots, n\}$, with $y_0 = 0$ and $0 < y_1 < y_2 < \ldots < y_n$. In addition, the project produces a nonassignable rent, b, which is captured by the entrepreneur if the project is successful. It is assumed that the project's outcome is observable at no cost, and that the financier knows the value of such rent.

In this model, I assume that the probability distribution of the project's returns is an endogenous variable because it depends on the entrepreneur's effort. Moreover, I also assume that the entrepreneur incurs a cost for each level of effort that he chooses. One way to model this situation would be to take the entrepreneur's effort as the choice variable. In that case, it would be necessary to specify a functional relationship between the probabilities and the effort, and a cost function that would depend on the effort. Instead, I use an approach wherein the choice variables are the probabilities themselves. Because the entrepreneur incurs a certain cost for each probability distribution that he chooses, the cost function depends on the probabilities $\{p_1, p_2, \ldots, p_n\}$, with $p_0 \equiv \{1 - \sum_{i=1}^{n} p_i\}$.

The main advantage of this approach is that it avoids some of the technical difficulties that frequently appear when solving a principal-agent problem [2]. In addition, the choice of a cost function that is strictly convex and strictly increasing in its arguments makes it possible to use convex programming theory in solving the model.

Assumption 3. Let $C(\cdot)$ denote the cost function. Then

$$C(p): p \rightarrow R^{+},$$

where $p = \{p_1, p_2, \ldots, p_n\}$, and $C(\cdot)$ is C^2, strictly convex, strictly increasing, and satisfies the condition $C(0) = 0$. In particular, I use the following cost function:

$$C(p) = \sum_{i=1}^{n} \tfrac{1}{2} a_i p_i^2$$

with $a_i > 0$, $\forall i \in \{1, 2, \ldots, n\}$.

Finally, it is assumed that the parameters of the model are such that the entrepreneur is not able to completely eliminate the risk of failure of the project, $p_0 > 0$, and that the feasible conditions, $0 \leq p_i < 1$, $\forall i \in \{1, 2, \ldots, n\}$, are satisfied.

3. The optimal contract

When the entrepreneur gets the necessary funds to finance his project from an outside source, a financier, the following question can be raised: What are the characteristics of the optimal contract that will rule their relationship? Given that the effort chosen by the entrepreneur is not observable, and that at the beginning of the period the financier will supply a fixed amount of funds equal to $\bar{I}$ (because, by assumption, the entrepreneur has no funds), then the only thing left to be defined by the contract is the payment that the entrepreneur will make to the financier at the end of the period. This payment will be contingent on the observable information available at that time, that is, on the outcome of the project. The rent captured by the entrepreneur when the project is successful cannot be contracted on because, by assumption, it is nonassignable [3].

Let r_i be the payment required by the financier contingent on the outcome y_i. As a result of the limited liability condition, we have $r_0 = 0$ because, by assumption, $y_0 = 0$ and $r_i \leq y_i$, $\forall i \in \{1, 2, \ldots, n\}$. Based on this definition, the contract between the two parties can be written as $(\bar{I}, r)$, where $\bar{I}$ is the number of

[2] For a discussion of the advantages associated with this approach, see Holmström (1979).

[3] Note that under these circumstances, even when the principal and the agent are both risk neutral, the first-best solution will not be reached. The well-known procedure that implements the first-best solution in this class of models-that is, the procedure whereby the principal demands a fixed payment and makes the agent the residual claimant-cannot be implemented here because the agent has no funds and state 0 (the state where the project's outcome is zero) occurs with a positive probability.

monetary units supplied by the financier, and r is the vector of (non-negative) contingent payments made by the entrepreneur.

As we will see, the revenue raised by the optimal contract will depend on the market power of the entrepreneur relative to that of the financier. There will be a continuum of possibilities limited by the following two extremes: First, suppose that there are many entrepreneurs with identical projects, but only one financier. In this case, the optimal contract will define a division of the returns that leaves to the entrepreneur only the absolute minimum needed to guarantee that he undertakes the project. Second, imagine now the opposite situation: perfect competition among the financiers. In this case, the optimal contract will give the financier only the required return to pay for the opportunity cost of the capital supplied to the entrepreneur at the beginning of the period.

The optimal contract that rules the relationship between the two parties is defined as the solution to the problem that maximizes the profits of the entrepreneur subject to the following constraints. The first are the incentive constraints, which are used to motivate the entrepreneur to choose the appropriate probability distribution (p) given the payment schedule (r) defined in the contract[4]. The second is the participation constraint, which is used to guarantee that the financier's profits are at least equal to the minimum he requires to finance the project. The third is the limited liability condition.

Proposition 1: The optimal contract to the problem defined here is $(\bar{I}, r^*)$, *where*

$$r_0^* = 0, \text{ and } r_i^* = (y_i + b)[1 - f(\lambda)] \quad \forall i \in \{1, 2, \ldots, n\},$$

$$p_0^* = 1 - \sum_{i=1}^{n} p_i^*, \quad \text{and} \quad p_i^* = \frac{y_i + b}{a_i} f(\lambda),$$

$$f(\lambda) = \frac{1-\lambda}{1-2\lambda}, \qquad \lambda^* = \tfrac{1}{2} - \tfrac{1}{2}\left(\frac{H}{H - 4[\bar{I}(1+r) + \overline{\Pi}_F]}\right)^{1/2},$$

$$H \equiv \sum_{i=1}^{n} \frac{(y_i + b)^2}{a_i},$$

and $\overline{\Pi}_F$ *are the profits required by the financier.*

For proof of this proposition, see Appendix A.

Looking at this proposition, we see that, as expected, the revenue raised by the optimal contract depends on the profits required by the financier, $\overline{\Pi}_F$. It can be shown that as these profits increase: (i) the entrepreneur's payments to the

[4] The importance of the incentive constraints is driven by the unobservability of the effort (p) chosen by the entrepreneur. Hence, it is through these constraints that the financier can find the right incentive to induce the entrepreneur to choose a certain probability distribution.

financier in each state (r_i^*) increase, (ii) the probabilities of the project's positive outcomes (p_i^*) decrease, while its probability of failure (p_0^*) increases, and (iii) the entrepreneur's profits (Π_E^*) decrease. All of these variations occur at an increasing rate, meaning that the moral hazard costs due to the unobservability of the entrepreneur's effort rise at an increasing rate with the financier's profits.

4. Debt and equity as optimal contracts

The optimal contract found in the previous section was not characterized in terms of the financial instruments known in the corporate finance literature. This section proves that such a contract can be spanned by a (unique) combination of debt and equity, which shows the optimality of these financial instruments in the model adopted here. The section ends with an analysis of some comparative static results.

Suppose the financier decides to use debt and/or equity to finance the project. Then the new contract can be written as $(\bar{I}, \alpha, d)$, where $\bar{I}$ has the same definition as before, α is the proportion of the firm's equity held by the financier, $(1-\alpha)$ is the proportion of the firm's equity held by the entrepreneur, and d is the face value of debt borrowed by the entrepreneur. As usual, I assume that equityholders are the residual claimants and that they are protected by limited liability.

Proposition 2: The optimal contract defined in proposition 1 can be replicated by a unique combination of debt and equity, that is, by the contract $(\bar{I}, \alpha^*, d^*)$, where

$$\alpha^* = 1 - f(\lambda), \qquad d^* = b\frac{1-f(\lambda)}{f(\lambda)},$$

and where $f(\lambda)$ and λ^* are equal to the definitions presented in proposition 1.

A formal proof of this proposition is contained in Appendix B. It is based on the following spanning argument: If there exists a feasible and unique combination of α and d that motivates the entrepreneur to choose the second-best outcome p^* and at the same time generates the same revenue to the financier as r^*, then it must be the case that debt and equity are optimal contracts. Equityholders' limited liability is a necessary condition for this spanning argument, because it explains why in state 0 (the state where the project's outcome is zero) the financier in his position as a debtholder receives no income from the firm's equityholders (the financier himself and the entrepreneur).

As is well known, when the investment's outcome depends on two variables controlled by the agent, then, in general, a combination of two financial instruments must be used to replicate the optimal contract. This, however, is not a requirement for the results derived in this paper. The simultaneous optimality of debt and equity contracts holds in the present model, regardless of the number of states where the project produces a positive outcome (n), that is, regardless of the number of variables-the effort chosen in each of those states-controlled by the agent.

Proposition 2 makes it clear that, were it not for the nonassignable rent, the optimal contract would be replicated by an equity contract. When such a rent exists, as the results in that proposition show, equity alone no longer solves the problem. In this case, debt is the contract that must be added to equity in order to span the optimal contract, for the following reason: The nonassignable rent is captured by the entrepreneur when the project is successful, which happens in all of the states where it produces a positive outcome. The value of this rent to the entrepreneur allows the financier to demand a fixed payment in each of those states without distorting the entrepreneur's effort incentives. This payment is demanded through the debt part of the contract. For this reason, the face value of the debt is never larger than the value of the rent; if it were, it would distort the entrepreneur's incentives in the states where the project produces a lower outcome.

Using the functional forms of both α^* and d^* and taking into consideration the fact that $\lambda^* = \lambda(y_i, a_i, b, \bar{I}, \overline{\Pi}_{\mathrm{F}}), \forall i \in \{1, 2, \ldots, n\}$, it is possible to show the following signs for the partial derivatives:

$$\alpha^* = \alpha\Big(\underset{-}{y_i}, \underset{+}{a_i}, \underset{-}{b}, \underset{+}{\bar{I}}, \underset{+}{\overline{\Pi}_{\mathrm{F}}}\Big), \qquad d^* = d\Big(\underset{-}{y_i}, \underset{+}{a_i}, \underset{?}{b}, \underset{+}{\bar{I}}, \underset{+}{\overline{\Pi}_{\mathrm{F}}}\Big).$$

The explanation for the negative relation between the optimal value of the financial instruments and the outcomes of the project is that when y_i increases, the financier gets more revenue through his participation in the equity of the firm. In addition, an increase in the outcomes of the project motivates the entrepreneur to choose a higher level of effort. As a result, it is possible for the financier to obtain the same expected profit, $\overline{\Pi}_{\mathrm{F}}$, by holding less equity and charging a lower face value of debt. A similar argument can be used to explain the signs of the other partial derivatives.

Note that as the funding provided by the financier, $\bar{I}$, increases, he raises both his equity position in the firm and the face value of debt. As a result, this model would predict a positive relationship between the financier's stake in the firm's capital and the size of the loan he gives the firm; that is, a larger stockholding would be associated with more lending.

Finally, it is possible to show that as the investment made by the financier increases, the proportion of the firm's equity held by the financier relative to the face value of debt decreases-that is,

$$\frac{\alpha^*}{d^*} = g\big(\underset{-}{\bar{I}}, \underset{-}{\overline{\Pi}_{\mathrm{F}}}\big).$$

This occurs because the level of effort that the entrepreneur puts into the project is more sensitive to the proportion of equity he holds than to the loan he has to pay. Because of this, when the financier needs to raise the profit he gets from financing such a project, he increases the value of both financial instruments, but raises the value of debt more than equity.

Little empirical research has been done on the relationship between lending conditions and banks' equity holdings. This is largely due to the difficulties of finding appropriate micro-level data. However, there has been some work on the relationship between stockholdings and lending, specifically on whether financial institutions own more equity in firms in which they own more debt. Incentive arguments or control-rights arguments would suggest the existence of a positive relationship between these variables. Prowse (1990) and Flath (1993) find evidence of such a relationship in Japan, while Cable (1985) finds evidence of a positive relationship between bank borrowing, voting control, and board representation in Germany. German banks, in addition to being allowed to invest in the equity of nonfinancial firms, are also permitted to perform proxy voting, that is, to vote the shares of other shareholders that are deposited with them.

5. Final remarks

As is well documented in the literature, when an investment project's outcome depends on two variables controlled by the entrepreneur, in general, two financial instruments are needed to generate the second-best solution. This result has been used on some occasions to show the simultaneous optimality of debt and equity contracts.

The principal-agent model developed in this paper shows that it is still possible to get simultaneous optimality of debt and equity contracts when the investment's outcome depends on more than two control variables. In particular, it shows that such optimality holds regardless of the number of variables controlled by the entrepreneur.

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necessarily those of the Federal Reserve Bank of Cleveland or of the Board of Governors of the Federal Reserve System.

Appendix A. Proof of proposition 1

In order to prove this proposition, it is necessary to solve a principal-agent problem, which I do using a two-step procedure [5]. In the first step, the incentive constraints are determined. In the second step, the profits of the entrepreneur are maximized over the set of implementable choices of p.

A.1. First step – The entrepreneur's problem

For a given payment schedule $\bar{r}$, the entrepreneur must solve the following problem:

$$\begin{aligned} \max_{p} \quad & \Pi_{\mathrm{E}} = \sum_{i=1}^{n} p_i(y_i + b - \bar{r}_i) - C(p) \\ \text{s.t.} \quad & p.e \leq 1 \\ & p \geq 0. \end{aligned}$$

Because the objective function is strictly concave and the feasible set is convex and compact, this is a convex programming problem with a unique solution. Moreover, the Kuhn–Tucker conditions are necessary and sufficient for a solution.

Taking into account the Kuhn–Tucker conditions and the existence of limited liability, it is possible to conclude that if $\bar{r}_i \leq y_i$, then $p_i > 0$; otherwise, $p_i = 0$. For the case where $\bar{r}_i \leq y_i$, the incentive constraints are

$$y_i + b - r_i - a_i p_i = 0 \quad \forall i \in \{1, 2, \ldots, n\}. \tag{A.1}$$

A.2. Second step – The financier's problem

In this step, the entrepreneur's profits are maximized over the set of implementable choices of p. This set is defined by the incentive constraints, the financier's participation constraint, and the limited liability condition. The idea behind this step is that given the profits required by financiers, $\overline{\Pi}_{\mathrm{F}}$, they compete

[5] This procedure, which is known in the literature as the 'first-order approach', can be used to solve some principal-agent problems (see Rogerson, 1985; Jewitt, 1988), but not others (see Mirrlees, 1975). The present example falls into the first category.

in order to offer the best feasible contract to the entrepreneur. The problem that a financier must solve can be formalized as follows:

$$\begin{aligned}
\max_{r} \quad & \Pi_{\mathrm{E}} = \sum_{i=1}^{n} p_i(y_i + b - r_i) - C(p) \\
\text{s.t.} \quad & y_i + b - r_i - a_i p_i = 0 \quad \forall i \in \{1, 2, \ldots, n\} \\
& \sum_{i=1}^{n} p_i r_i - \bar{I}(1+s) \geq \overline{\Pi}_{\mathrm{F}} \\
& 0 \leq r_i \leq y_i \quad \forall i \in \{1, 2, \ldots, n\}.
\end{aligned}$$

Note that by changing the profits required by the financier in the participation constraint (between zero, which occurs when there is perfect competition to finance the project, and the maximum amount of profits that he can get, $[H/4 - \bar{I}(1+s)]$, which occurs when there is only one financier and many identical entrepreneurs), it is possible to find all of the admissible divisions of the project's returns between the entrepreneur and the financier, and all of the efficient contracts. In the process of finding all of these divisions, it is necessary to ensure that the entrepreneur's profits are sufficient to cover his opportunity cost of undertaking the project, which I assume to be zero. Furthermore, since the incentive constraints were derived under the assumption that $r_i \leq y_i$, which implies $p_i > 0$, $\forall i \in \{0, 1, 2, \ldots, n\}$, the parameters of the model have to be such that its solution satisfies these conditions.

The one-to-one relation that exists between r_i and p_i in the incentive constraints can be used to rewrite the problem as a function of p_i. Given that the financier's participation constraint will be verified exactly (otherwise the entrepreneur's profits could be increased simply by offering him a new contract with a lower r_i), we can 'add' the financier's participation constraint to the objective function without altering the solution to the problem. As a result of these changes, the problem to be solved becomes

$$\begin{aligned}
\max_{p} \quad & \Pi_{\mathrm{E}} = \sum_{i=1}^{n} p_i y_i - C(p) - \bar{I}(1+s) - \overline{\Pi}_{\mathrm{F}} \\
\text{s.t.} \quad & \sum_{i=1}^{n} p_i(y_i + b - a_i p_i) - \bar{I}(1+s) \geq \overline{\Pi}_{\mathrm{F}} \\
& p \geq 0.
\end{aligned}$$

Given that the objective function is strictly concave and the feasible set is compact and convex (the constraint is strictly concave), we are again in the presence of a convex programming problem, and the usual results apply. Defining

λ as the Lagrange multiplier associated with the problem's constraint and solving it, we find the results that are presented in proposition 1 [6].

Appendix B. Proof of proposition 2

B.1. First step – The entrepreneur's problem

For a given percentage of equity held by the financier, $\bar{\alpha}$, and a given face value of debt, $\bar{d}$, the entrepreneur must solve the following problem:

$$\begin{aligned} \max_{p} \quad & \Pi_{\mathrm{E}} = \sum_{i=1}^{n} p_i \left[(1-\bar{\alpha})\left(y_i - \bar{d}\right) + b \right] - C(p) \\ \text{s.t.} \quad & p.e \le 1 \\ & p \ge 0. \end{aligned}$$

Once again, this is a convex programming problem, so the usual results apply. For the case where $p_i > 0$ the incentive constraints are

$$(1-\alpha)(y_i - d) + b - a_i p_i = 0, \quad \forall i \in \{1, 2, \dots, n\}.$$

B.2. Second step – The financier's problem

In this step, instead of following the procedure adopted to prove proposition 1, I use a different approach based on a spanning argument. The idea is as follows: If it is possible to find a feasible combination of α and d that motivates the entrepreneur, through the incentive constraints, to choose the probability distribution p^*, and if such a combination generates the same revenue to the financier as does r^*, then it must be the solution to the financier's problem. This proves that the optimal contract can be spanned by a combination of debt and equity.

From the incentive constraints and the second-best probability distribution p^*, we can find α^* and d^*. If these are feasible values, then the last thing left to be shown is that the combination (α^*, d^*) generates the same revenue to the financier as does r^*. This is apparent immediately once we recognize that $\alpha(y_i - d) + d = r_i$, and once we take into account equityholders' limited liability condition, which explains why in state 0 (the state where the project's outcome is equal to zero) the financier in his position as a debtholder receives no payment from the firm's equityholders (the financier himself and the entrepreneur).

[6] The Lagrangean for this problem was defined as $L(p, \lambda) = \sum_{i=1}^{n} p_i y_i - C(p) - \bar{I}(1+s) - \overline{\Pi}_{\mathrm{F}} + \lambda[\overline{\Pi}_{\mathrm{F}} + \bar{I}(1+s) - \sum_{i=1}^{n} p_i(y_i + b - a_i p_i)]$, where $\lambda \le 0$. Note that $\lambda = 0$ does not solve the problem. In this case we would have the first-best solution, but the constraint would not be verified. As a result, we have $\lambda < 0$.

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