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OLIVER HART AND BENGT HOLMSTRÖM: CONTRACT THEORY

The Committee for the Prize in Economic Sciences in Memory of Alfred Nobel

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BOX 50005 (LILLA FRESCATIVÄGEN 4 A), SE-104 05 STOCKHOLM, SWEDEN
TEL +46 8 673 95 00, INFO@KVA.SE ★ HTTP://KVA.SE

Contract Theory

1 Introduction

An eternal obstacle to human cooperation is that people have different interests. In modern societies, conflicts of interests are often mitigated – if not completely resolved – by contractual arrangements. Well-designed contracts provide incentives for the contracting parties to exploit the prospective gains from cooperation. For example, labor contracts include pay and promotion conditions that are designed to retain and motivate employees; insurance contracts combine the sharing of risk with deductibles and co-payments to encourage clients to exercise caution; credit contracts specify payments and decision rights aimed at protecting the lender, while encouraging sound decisions by borrowers.

The idea that incentives must be aligned to exploit the gains from cooperation has a long history within economics. In the 1700's, Adam Smith argued that sharecropping contracts do not give tenants sufficient incentives to improve the land. In the 1930's, Chester Barnard considered how employees could be incentivized to contribute effort within large organizations.[1] This year's laureates have approached these old ideas using theoretical models that have given us new insights into the nature of optimal contracts. The models have also allowed researchers to sharpen existing arguments and pursue them to their logical conclusions. As a result, contract theory has made major strides during the last few decades. Today, incentive problems are almost universally seen through its lens. The theory has had a major impact on organizational economics and corporate finance, and it has deeply influenced other fields such as industrial organization, labor economics, public economics, political science, and law.

A classic contracting problem has the following structure. A *principal* engages an *agent* to take certain actions on the principal's behalf. However, the principal cannot directly observe the agent's actions, which creates a problem of *moral hazard*: the agent may take actions that increase his own payoff but reduce the overall surplus of the relationship. To be specific, suppose the principal is the main shareholder of a company and the agent is the company's manager. As Adam Smith noted, the separation of ownership and control in a company might cause the manager to make decisions contrary to the interests of shareholders.[2]

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[1] Laffont and Martimort (2002) provide a brief history of incentives in economic thought.

[2]

> "The directors of such companies ... , being the managers rather of other people's

To alleviate this moral-hazard problem, the principal may offer a compensation package which ties the manager's income to some (observable and verifiable) performance measure. We refer to this as *paying for performance*. The company's profit or stock-market value are frequently used performance measures, but they have well-known drawbacks. They may depend largely on factors beyond the manager's control, so that the manager would be rewarded for luck. Intuitively, it would be desirable to filter out as much of the luck component as possible, perhaps by measuring the firm's performance relative to other firms in the same industry. But any performance measure is likely to be imprecise and noisy, so in the end the optimal compensation schedule must trade off incentive-provision against risk-sharing.

To go beyond these vague intuitions requires a formal analysis. Some formal results were obtained in 1975 by James Mirrlees, the 1996 Economics Laureate. In 1979, Bengt Holmström provided a formalization which would prove to have a lasting impact. In addition to characterizing the optimal trade-off between incentives and risk-sharing, Holmström's article contained a fundamental result on optimal performance measures, namely the *informativeness principle*. A second generation of moral hazard models, developed in the 1980s by Holmström, sometimes by himself and sometimes with coauthors – in particular Paul Milgrom – introduced dynamic moral hazard, multi-tasking and other key issues. Personnel economics, and organizational economics more broadly, have been strongly influenced by this line of work. We discuss the pay-for-performance approach in more detail in Section 2.

Paying for performance requires both the ability to write sufficiently detailed contracts *ex ante*, as well as the ability to measure and verify performance *ex post*. These requirements are sometimes hard to satisfy. Suppose, for example, that the agent is a researcher whose delegated task is to develop a new technology for the principal's company. Due to the uncertainties inherent in the R&D process, it may be impossible to specify *ex ante* exactly what the innovation should be. Moreover, neither the quality of the new technology nor its impact on the principal's profit may be verifiable *ex post*. Since performance-based contracts may not be of much use in this kind of situation, an alternative approach is needed. The *incomplete contracting* approach, pioneered by Oliver Hart and his collaborators Sanford Grossman and John Moore, emphasizes the *allocation of decision rights*.

Decision rights are often determined by property rights – i.e., by ownership. In the R&D example, one possibility is that the agent is employed with a fixed salary by the principal. In this case, the agent has no *ex post* bargaining power: the principal owns any innovation and can use it freely. Another possibility is that the researcher independently owns any innovation that he develops. He

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money than of their own, it cannot well be expected that they should watch over it with the same anxious vigilance with which the partners in a private company frequently watch over their own... Negligence and profusion, therefore, must always prevail, more or less, in the management of the affairs of such a company" (Smith, 1776, Book 5, Chapter 1, Part 3).

can then deny the principal the use of the new technology, or sell it to her at a price determined by some bargaining process. Presumably, he will extract a higher price if the technology is of high quality. This means that the agent has more high-powered incentives as an independent researcher than as an employee, because his income is more sensitive to the quality of the innovation. On the other hand, the independent researcher may lack sufficient incentive to tailor-make the innovation for the principal's purposes, because his bargaining power will be greater if the innovation has many alternative uses.

Although this example is stylized, it does illustrate an important insight: property rights generate bargaining power, which in turn determines incentives. More generally, when performance-based contracts are hard to write or hard to enforce, carefully allocated decision rights may produce good incentives and thus substitute for contractually specified rewards. This insight is a cornerstone in the theory of incomplete contracts. The theory has been highly influential within corporate finance and organizational economics, where it has been used to analyze a broad range of issues, such as the costs and benefits of mergers, the distribution of authority within organizations, whether or not providers of public services should be privately owned, and how outside owners can control a company's inside managers through the design of corporate governance and capital structure. We discuss the allocation of decision rights, as formalized by the incomplete contracts theory, in Section 3.

This document provides a concise overview of Oliver Hart's and Bengt Holmström's most important contributions to contract theory. As will become clear, these contributions are highly complementary. Since the theory has too many extensions and applications to allow for a full-fledged survey, we must necessarily be very selective.[3] It is equally difficult to provide an extensive history of thought – we will not go far beyond the above-mentioned examples.

As another confiner, in this document we will mostly abstract from psychological and sociological aspects of contracting, and focus on the need to align conflicting interests among rational and selfish materialists. The basic premise is that people respond to material incentives; this is supported by considerable evidence across a wide range of settings.[4] But the relevance of contract theory does not rely on agents being completely rational and selfish. Many analytical results continue to hold under alternative psychological and sociological assumptions. In fact, the same theoretical framework can be used to derive novel results for unselfish or boundedly rational agents, or agents with intrinsic non-material motivations. For example, recent research, extending the traditional theory, has clarified why and when material incentives may fail to induce desired behavior, and why it may sometimes be optimal to provide only weak material incentives.[5] Indeed, the laureates themselves have recently relaxed the standard rationality assumptions.[6]

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[3] For excellent introductions to contract theory, see Bolton and Dewatripont (2004), Laffont and Martimort (2002), and Salanié (2005).

[4] Identifying the effect of incentives on behavior is made difficult by the fact that, in most cases, observed contracts are endogenous. If individuals with different contracts have different characteristics, then we do not know if differences in behavior are due to the different contracts or to the difference in characteristics. One way to avoid this endogeneity problem is to study situations where contracts differ due to some exogenous reason. The ideal is of course a randomized experiment – a famous example is the RAND Health Insurance Experiment, which showed (against the expectations of some specialists) the existence of moral hazard in health insurance (Newhouse et al., 1993; see Aron-Dine et al., 2013, for a recent review). Another well-known study is Lazear (2000), studying the switch from fixed to piece-rate pay for an auto glass company after an exogenous management change. Lazear found that this generated a 44 percent increase in output per worker; about half of this was due to incentive effects on the average worker (the other half was due to selection, i.e., more productive workers choosing to work for the company). In a field experiment in a tree-planting firm, Shearer (2004) found productivity gains of more than 20% when switching from fixed wages to piece-rates. Clemens

Finally, by assuming that the parties have symmetric information at the time of contracting, we abstract from the problem of *adverse selection*. Adverse selection is important in many applications. However, research related to this area has been recognized by the 1996 Prize to James Mirrlees and William Vickrey for contributions to the economic theory of incentives under asymmetric information, by the 2001 Prize to George Akerlof, Michael Spence, and Joseph Stiglitz for analyses of markets with asymmetric information, and by the 2007 Prize to Leonid Hurwicz, Eric Maskin, and Roger Myerson for the foundations of mechanism-design theory. Both moral hazard and adverse selection were important building blocks for the 2014 Prize to Jean Tirole for the analysis of market power and regulation.

2 Complete Contracts: Paying for Performance

In this section, we review Bengt Holmström's contributions to contract theory. The first subsection discusses some basic results in the context of a principal–agent model, while the second subsection discusses some extensions to the basic model.

2.1 Optimal Incentive Contracts

A simple formal framework will be used to illustrate and connect the main contributions. An agent, A, works a single period for a principal, P. The agent takes an action a from some interval $[\underline{a}, \bar{a}]$. This generates a cost $c(a)$ for the agent and a benefit $\beta = b(a) + \varepsilon$ for the principal, where ε is a random noise term. Since we are concerned with conflicts of interest, we assume both b and c are increasing functions of a, so that, all else equal, the principal prefers a higher a while the agent prefers a lower a. We may interpret a as the agent's "effort".[7]

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and Gottlieb (2014) found that a two percent increase in the local Medicaid reimbursement rate entailed a three percent increase in physicians' care provision. Asch (1990) found that Navy recruiters vary their recruitment effort in response to incentives. See Nagin et al. (2002), or Bandiera et al. (2005) for more evidence on the effect of incentives on behavior.

[5] See for example Francois (2000), Benabou and Tirole (2003, 2006), Besley and Ghatak (2005), and Bowles and Polanya-Reyes (2012).

[6] See Hart and Moore (2008), Hart and Holmström (2010), and Fehr, Hart, and Zehnder (2011).

[7] We may interpret $\underline{a}$ as the lowest effort the agent can get away with without being caught shirking. Alternatively, it sometimes makes sense for $c(a)$ to be non-monotonic. For example,

Assume further that both b and c are differentiable, b is concave and c is convex. For any random variable x, let $E(x)$ and $Var(x)$ denote the expected value and variance of x, respectively. Without loss of generality, assume $E(\varepsilon) = 0$.

This simple model captures the essence of many important real-life settings. For example, the agent could be a worker, a CEO, an entrepreneur, a lawyer, a firm, or a supplier of public services; the corresponding principal could be an employer, a board of directors, a venture capitalist, a client, a regulator, or a public authority. In many such settings, the outcome is random, and risk-sharing is a crucial aspect of the contracting problem. We capture this by the noise term ε.

Let t denote a payment, or transfer, from the principal to the agent. Note that $t > 0$ indicates a payment from P to A, while $t < 0$ is a payment in the opposite direction. These payments would be constrained by the financial resources that P and A have at their disposal. For now, we assume both parties have large enough resources so that such financial constraints can be neglected. Also, since the principal is often richer or better diversified than the agent, let us assume that P is risk-neutral and A is risk-averse. Specifically, suppose the principal's expected utility is

$$U_P = b(a) - E(t), \tag{1}$$

while the agent's expected utility is

$$U_A = -c(a) + E(t) - \frac{1}{2} r Var(t), \tag{2}$$

where $r > 0$ measures the degree of risk aversion.

First-Best Benchmark The total surplus from the relation is

$$U_P + U_A = b(a) - c(a) - \frac{1}{2} r Var(t), \tag{3}$$

where the last term is the utility cost of A's risk-bearing. Assume that a unique action $a^* \in [\underline{a}, \bar{a}]$ maximizes $b(a) - c(a)$. Uniqueness of a^* is guaranteed if either b is strictly concave, c is strictly convex, or both. Using primes to denote derivatives, assuming $b'(\underline{a}) > 0$ and $c'(\underline{a}) = 0$ guarantees that $a^* > \underline{a}$. It is also convenient to assume that $c'(\bar{a})$ is very large, so that $a^* < \bar{a}$. The total surplus is maximized when $a = a^*$ and A bears no risk: $Var(t) = 0$. The outcome is then said to be *first-best*.

If the action a were observable, and if the principal could write – and commit to – a contract that directly linked the transfer to the agent's action, $t = t(a)$, then it would be easy to implement the first-best. The principal could merely increase the difference $t(a^*) - t(a)$ until $-c(a^*) + t(a^*) > -c(a) + t(a)$ for all $a \neq$

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a worker may prefer to exert some effort rather than being completely idle. To capture this we could assume $a \in [0, \bar{a}]$, with $c(a)$ decreasing on $[0, \underline{a}]$ and increasing on $[\underline{a}, \bar{a}]$. In this case the worker would never choose $a < \underline{a}$, so we may just as well restrict attention to the interval $[\underline{a}, \bar{a}]$.

a^*. The agent would then be induced to take action a^*, and the principal would bear all the risk associated with random variable ε. This would be efficient, since P is risk-neutral and A is risk-averse.[8] By adding or subtracting a constant to or from the transfer schedule t, any desired distribution of surplus between P and A can be achieved. Preventing the agent from taking the "wrong" action $a \neq a^*$ may require a high pecuniary penalty $t(a) << 0$.[9] But the assumption we highlight here is that the transfer t can be conditioned directly on the action a. This assumption is very strong, and dropping it leads to the "classic" moral-hazard model.

Hidden Action: The Classic Moral-Hazard Model In the classic moral-hazard model, it is not possible to write a contingent transfer schedule $t(a)$ into the contract. The justification for this is typically the *hidden action* assumption: a is not observable. However, even if the action could be observed, it may be hard to fully describe it in advance – and even if it could be both described and observed, it might be impossible for a court (or some other contract-enforcer) to verify what action was taken. In any case, following the classic moral-hazard literature, we assume the transfer is based on an *imprecise performance measure*. Specifically, it is based on the benefit the principal derives from the agent's action, $t = t(\beta)$. The benefit $\beta = b(a) + \varepsilon$ is assumed to be both observable and verifiable by a court, but it is only an imperfect indicator of the agent's action (due to the fluctuating ε). This is often a realistic situation. For example, while a board of directors may not observe exactly how the CEO runs the company, they do observe the stock price (and a number of other accounting measures). Empirically, a typical CEO's pay is strongly dependent on his company's stock-market performance.[10]

If the agent is risk-neutral ($r = 0$) and has sufficient financial resources, then the contracting problem has a straightforward solution, a "franchise contract" where A pays a fixed fee f to P and in return gets all of the realized benefit: $t(\beta) = \beta - f$. Since the agent becomes a residual claimant to any surplus he generates, he has the right incentives to trade off costs and benefits: he will maximize $b(a) - c(a)$ by choosing the first-best action a^*. The agent has to carry all the risk, but as long as $r = 0$ this is not costly. The fixed fee f can be used to divide the surplus in any desired fashion.[11]

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[8] If both P and A were risk-averse, they should write a second contract on the realization of ε to optimize risk-sharing. This would be straightforward in this setting, with observable actions and perfect commitment.

[9] Alternatively, P could impose a *non-pecuniary* penalty (if such a penalty is available) on A when $a \neq a^*$.

[10] See e.g. Murphy (1985). We discuss the evidence on CEO compensation in more detail below.

[11] Another interpretation of the optimal contract is that A buys the project from P for a price f. This relates to Jensen and Meckling's (1976) insight that having the manager own the equity of the firm alleviates moral hazard. They use this insight to rationalize debt financing, which allows a founder-manager to keep the equity of the firm. Innes (1990) provides a more formal model, deriving debt as an optimal financial contract in a setting with risk-neutral agents and limited liability constraints. Of course, managerial wealth constraints may be binding. (In the context of our model, the manager needs enough funds of her own to afford

However, we will consider the more interesting case where the agent is risk-averse, $r > 0$, so that it is not optimal for him to bear all the risk. The gain from high-powered incentives then has to be weighed against the loss from suboptimal risk-sharing. This trade-off between incentives and risk-sharing is a classic problem in incentive theory.[12] Mirrlees (1975) showed that, in some situations, the principal can approximately implement the first-best by penalizing the agent very heavily, $t(\beta) << 0$, when β takes values that would have been highly unlikely to occur, had the agent chosen the desired action. This is not quite what legal contracts in modern societies look like, and in fact the subsequent literature emphasized situations where Mirrlees's solution (a low-probability threat of extreme punishment) would be infeasible (e.g., Grossman and Hart, 1983a).

The Informativeness Principle Let us reflect on a more general feature of Mirrlees's argument, namely, that rewards should be based on the information that the realized value β carries about the action a. Of course, when the contract is optimally specified, A will rationally take the desired action, and P knows this. Yet, the conditional probabilities of observing β after different actions – as in a statistical inference problem – will be the key to designing an optimal contract. Since the agent's risk-bearing is linked to the quality of inference, any information that facilitates inference will be valuable.

Intuitively, the agent's compensation should depend on variables (signals) that provide information about his action. This intuition is encapsulated in the *informativeness principle* (Holmström, 1979, and Shavell, 1979). Formally, suppose P is considering making the transfer t a function of some signal s in addition to β. The informativeness principle, as formulated and proved by Holmström (1979), implies that she should do so if and only if β is not a sufficient statistic for a given (β, s).[13]

This result has important practical implications. In terms of the model above, a signal s that is correlated with the noise ε is potentially valuable to the principal, whereas a signal that is uncorrelated with both a and ε is always useless. In the context of managerial compensation, the manager's pay should depend not only on accounting measures and the firm's own stock price, but also on signals that are correlated with the stock price, such as observable cost and demand conditions or the stock prices of other firms in the same industry.

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to pay f). As a result, investors will not fund projects unless the manager has enough wealth to invest to guarantee sufficiently strong incentives. Holmström and Tirole (1997, 1998, 2001) show how a simple model of managerial wealth constraints can be used to investigate a number of important issues in corporate finance, including the impact of wealth shocks on the banking system, banking regulation, and the role of public liquidity provision for firms. The Holmström and Tirole model has become a tractable workhorse theory for analyzing various corporate finance and financial intermediation issues (see, e.g., Plantin and Rochet, 2006, or Adrian and Shin, 2008).

[12] Early treatments of the moral-hazard problem, by Wilson (1969), Spence and Zeckhauser (1971) and Ross (1973), primarily studied special cases in which the first-best outcome can be attained.

[13] Shavell (1979) proved the "if" but not the "only if" part. Also, Harris and Raviv (1979) is a contemporaneous paper providing a less general informativeness principle result.

Linking the manager's pay to these signals helps to filter out the effect of the manager's performance from general industry and macroeconomic fluctuations that are beyond the manager's control.[14]

The informativeness principle relies on statistical considerations only, with no reference to preference parameters. Of course, the agent's risk aversion will influence the overall variability of the optimal transfer schedule, but the relative importance of different kinds of information should be determined by the rules of optimal statistical inference (with noisier signals given less weight).

The Informativeness Principle in Empirical Work The informativeness principle predicts that when an agent's pay is linked to some performance measure, then the contract should be indexed so as to filter out the impact of exogenous factors on the agent's pay. Since the benefit from indexation relies only on statistical considerations, it is possible to test this prediction without precise knowledge of the agent's risk preferences (assuming only that the agent is risk-averse). It turns out that many chief executive officers have contracts that fail to provide such indexation. They are thus "paid for luck", contradicting the prediction of the informativeness principle (Bertrand and Mullainathan, 2001).

This finding suggests that practitioners may fail to design optimal contracts. Indeed, Bertrand and Mullainathan (2001) find that firms with a dominant shareholder have more indexation of CEO compensation than firms without such a dominant shareholder. This suggests that the former firms are better governed: the dominant shareholder is a true principal. Without a dominant shareholder, the CEO may be able to capture the contracting process and get paid for luck. This illustrates how contract theory can guide empirical work and provide a lens through which we can view CEO compensation data with the objective of understanding good (or bad) corporate governance.

The Shape of the Optimal Contract The informativeness principle is a general result which does not depend on specific preference parameters or on the particular shape of the optimal contract. But what does the classic moral-hazard model say about the shape of optimal contracts? Do they resemble the contracts we actually observe?

By assuming a finite number of possible outcomes, Grossman and Hart (1983a) could rigorously study the shape of the optimal contract in the classic moral-hazard model.[15] In particular, they found conditions under which $t(\beta)$ would be increasing in β.[16] In general, however, the optimal transfer schedule depends in delicate ways on the shape of the distribution of the noise term ε, often leading to complex, non-linear contracts. In reality, contracts often take simpler forms that seem to be at odds with this conclusion.

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[14] Using the insights from the informativeness principle, Holmström and Tirole (1993) investigate the role of stock market liquidity in determining optimal managerial compensation and incentives. In their model, the efficient incentive contract involves tying CEO compensation to the firm's stock price, because the stock market incorporates performance information that cannot be extracted from the firm's current or future profit data. The reason is that the information of stock market investors will be incorporated in the stock price. The stock price will be more informative when the market for the stock is more liquid, since this makes it more profitable for investors to trade on information, which in turn improves their incentives to collect information about firm performance. They use this model to investigate the optimal ownership structure of firms, the equilibrium size of the stock market, and the social value of market liquidity and monitoring.

In an influential paper, Holmström and Milgrom (1987) argued that the complex shape of the theoretically optimal transfer schedule reflects an unrealistic feature of the model: the agent only takes a single action before outcomes are measured. In reality, the agent may work for weeks, months, and sometimes years, before his performance is evaluated. If a non-linear contract, such as the one proposed by Mirrlees, specifies a large punishment for performance below some particular level, the agent will be able to stay clear of that level by adjusting his behavior ("gaming"). In fact, all non-linearities may now become ineffective. Holmström and Milgrom (1987) showed that if an agent with constant absolute risk aversion controls the drift of a Brownian motion, the optimal contract is exactly linear. The linearity makes it possible to only rarely measure the agent's performance, and base the pay on aggregate performance measures.

The Holmström–Milgrom (1987) model explains common sharecropping contracts, as well as the use of shares to motivate managers. Their key insight, that non-linear compensation schedules are susceptible to gaming and therefore may be rendered inefficient, is supported by empirical studies (see Chevalier and Ellison, 1997). However, the model does not explain why many contracts have a pay floor, e.g., in the form of a sizable salary which is independent of performance.

Simple Analytics of Linear Contracts In the model of Holmström and Milgrom (1987), the optimal transfer schedule is linear in the observed benefit β,

$$t(\beta) = f + k\beta.$$

The slope of the transfer function, k, is the "incentive intensity": the higher the value of k, the more high-powered are the agent's incentives. Such contracts are not only realistic, but tractable enough to permit the analysis of a range of issues.

The model has transferable utility: the fixed component f can be used to redistribute surplus without affecting the total available surplus. The optimal contract sets action a and incentive intensity k to maximize the total surplus

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[15] From a mathematical point of view, there are several benefits to assuming a finite number of outcomes. First, if each outcome always occurs with a strictly positive probability, then Mirrlees's proposal (a low-probability threat of extreme punishment) is ruled out. Second, previous work had generally relied on the so-called first-order condition approach. But as Mirrlees (1975) showed, the first-order approach is not always valid. Grossman and Hart (1983a) showed how to solve the problem without ignoring second-order conditions.

[16] Perhaps surprisingly, this property need not always hold. For example, assume low effort is associated with moderate output; high effort is associated with higher expected output, but also entails some probability of very low output. It may then be optimal to pay the agent less when output is moderate than when it is very low, to discourage him from choosing low effort (despite the fact that the principal derives a larger benefit from moderate output than from very low output).

(3). If we make the simplifying assumption that the principal's benefit function has the linear form $b(a) = \zeta a$, where the constant $\zeta > 0$ represents the agent's productivity, then the optimal a and k are obtained from the following two equations:[17]

$$\zeta k = c'(a) \tag{7}$$

and

$$k = \frac{1}{1 + rc''(a)Var(\varepsilon)/\zeta^2}. \tag{8}$$

Assuming $c'' > 0$, we see that $0 < k < 1$. Generally, optimal incentives k are stronger when productivity (ζ) is higher, and when risk ($Var(\varepsilon)$) and risk aversion (r) are lower.

In the limit where either risk or risk aversion tends to zero, k will approach 1 and the contract becomes a franchise contract with A as a residual claimant. In the other limit, where either risk or risk aversion tends to infinity, k will approach 0, and A becomes a salaried employee whose compensation is independent of the outcome β.

Testing the Incentive-Risk Trade-Off Predictions involving the trade-off between incentives and risk-sharing are difficult to test directly, because the agent's degree of risk aversion is typically unobserved by the econometrician. At one extreme, a fixed-wage contract might be optimal for an extremely risk-averse agent; at the opposite extreme, a risk-neutral agent should carry all the risk. However, the classic theory does makes certain comparative statics predictions that do not rely on knowing the agent's risk preferences. In particular, *all else equal*, the theory predicts a negative relationship between risk (the variance of ε) and incentive power (the slope of the transfer function).

However, the "all else equal" assumption may be violated by systematic selection; less risk-averse agents (low r) may choose to work in more volatile

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[17] To derive the solution, start by noting that $Var(t) = Var(k\beta) = k^2 Var(\varepsilon)$ so that (3) becomes

$$U_P + U_A = \zeta a - c(a) - \frac{1}{2}rk^2 Var(\varepsilon) \tag{4}$$

From (2), A chooses a to maximize

$$-c(a) + k\zeta a - \frac{1}{2}rk^2 Var(\varepsilon) \tag{5}$$

which yields the first-order condition (7). Differentiating (7) with respect to k we find that A's response to an increase in incentive power is described by the relation

$$\frac{da}{dk} = \frac{\zeta}{c''(a)} \tag{6}$$

To derive the optimal incentive power, note that k must maximize (4), which in view of (6) yields the first-order condition

$$\zeta \frac{\zeta}{c''(a)} - c'(a)\frac{\zeta}{c''(a)} - rkVar(\varepsilon) = 0$$

Using (7) to eliminate c' we obtain (8).

environments. As these less risk-averse agents not only self-select into risky occupations, but also optimally assume more pay-performance risk, the predicted negative relationship may not be evident in the data (see Chiappori and Salanié, 2003).[18] The importance of this selection bias is illustrated by Ackerberg and Botticini (2002), who study agricultural contracts in Renaissance Italy. They find strong evidence that the type of crops that is cultivated is correlated with the tenant's characteristics – less risk-averse agents prefer riskier crops. Once the selection bias is accounted for, they find support for the classic theory.[19]

2.2 Extensions

In his subsequent work, Holmström extended the basic moral-hazard model in several directions, by analyzing cases with several tasks and several agents, as well as incorporating more dynamic aspects. This work resulted in some highly influential and important insights, which we now turn to.

The Multi-Tasking Model In the classic moral-hazard model, the agent's action is one-dimensional, and usually interpreted as "effort". However, in many applications the actions are complex and multi-dimensional, involving various activities that can only be imperfectly observed and measured (if at all). Trying to reward only the measurable activities may lead to dysfunctional behavior, as agents will then concentrate too much attention on the activities that are more likely to be rewarded (see Kerr, 1975, for an early and influential discussion). As Baker, Gibbons, and Murphy (1994) put it: "Business history is littered with firms that got what they paid for."For example, if a manager's bonus is too heavily tied to short-term earnings, he might sacrifice profitable long-term investments, since these investments involve lower current earnings, while the benefits arise far in the future.[20]

Formalizing such arguments requires a model where actions and outcomes are multi-dimensional. Such a model of *multi-tasking* was provided by Holmström and Milgrom (1991).[21] Suppose the agent takes two unobserved actions, a_1

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[18] While some studies do find that CEOs face stronger incentives when measurement is easier (see Aggarwal and Samwick, 1999), others find a positive relationship, or none at all, between risk and incentives (see Core, Guay, and Verrecchia, 2003). The evidence from franchising, retailing, and sharecropping is equally mixed (e.g., Lafontaine, 1992, Allen and Lueck, 1992).

[19] Prendergast (2002) suggested another reason for why the "all else equal" assumption may fail, making the predicted negative relationship between volatility and incentive power hard to identify in the data. In a more volatile environment, the principal may not know what the agent should do. Therefore, she may delegate more responsibility to the agent in such environments, but to constrain his behavior it would be optimal to design a high-powered incentive scheme. In contrast, in a less volatile environment the principal may simply tell the agent what to do, monitor him, and pay a fixed wage.

[20] Building on Holmström and Milgrom (1991), Benabou and Tirole (2016) show that increasing competition for talented CEOs can lead to an escalation of short-term performance pay, which in turn can lead to inefficient decreases in firms' long-term investment.

[21] Baker (1992) provides a related model in a setting where the principal's objective is not directly measurable, and parties can only contract on a measure imperfectly correlated with the principal's objective. Similar to the multi-tasking setting, this generally leads to weaker pay-performance incentives in the optimal contract.

and a_2, with cost function $c(a_1, a_2)$. Assume $\frac{\partial^2 c}{\partial a_1 \partial a_2} > 0$, implying that the two tasks are substitutes for the agent. Action a_i generates an output measure $\beta_i = b_i(a_i) + \varepsilon_i$. With linear pay-for-performance as in Holmström and Milgrom (1987), the transfer from P to A is $t(\beta_1, \beta_2) = f + k_1\beta_1 + k_2\beta_2$.

Suppose it is difficult to measure and reward action a_1 (the variance of ε_1 is large), but easy to measure and reward action a_2 (the variance of ε_2 is small). Since A is risk-averse and P is risk-neutral, optimal risk-sharing suggests that the first task should be only weakly incentivized (k_1 should be small). But if a_1 is important to the principal, a_2 should then also be weakly incentivized (k_2 should also be small) in order to prevent the agent from concentrating all his attention on a_2. Thus, it may be enough that one important task or outcome is difficult to measure for low overall incentive intensity to be optimal.

To illustrate, if A is a school teacher, then a_1 might represent stimulating student curiosity, responsibility, and the ability to think independently, while a_2 is "teaching to the test". The broader set of skills associated with a_1 can only be evaluated with considerable noise, and attempting to incentivize a_1 by tying the teacher's salary to such a measure would force him to bear too much risk. Incentivizing only a_2, say by tying the teacher's salary to the students' grades on standardized tests, will cause the teacher to neglect teaching the broader set of skills. Thus an optimal contract for the teacher may specify a fixed salary with no (explicit) incentive pay at all. This illustrates an important point about the informativeness principle, namely that its recommendation to link the agent's pay to any informative measure of effort applies only to the simplest case, where effort is one-dimensional. In more complex situations, where a principal wants to encourage a *balance* of activities, it may be optimal to ignore some performance-related information when determining the agent's compensation.

The multi-tasking model helps us understand many other organizational features, not just compensation contracts. For example, if A's cost of performing one task is very low because he gets some private (non-verifiable) return from it (or just likes it better), then P again may need to make sure that not all of A's attention is diverted to this task. For example, A may be a researcher with a keen interest in basic non-commercial research. Either his employer P must forbid A from engaging in the non-commercial research, or other tasks – commercial innovation – must be strongly incentivized. One way to achieve the latter is to let the researcher be his own boss. He then has complete freedom, but is only paid for commercially valuable research. Along these lines, Holmström and Milgrom (1994) extend the basic multi-tasking model in their 1991 paper and show that high-performance incentives, worker ownership of assets, and worker freedom from direct controls are complementary instruments for motivating workers. Thus, the model can provide an explanation for the empirical observation that weak incentives and lack of decision-making power tend to go hand in hand, while decision rights tend to go together with strong incentives.

Empirical Evidence on Multi-Tasking The basic premise behind Holmström and Milgrom's (1991, 1994) multi-tasking model is that agents will reallocate their effort away from uncompensated (non-incentivized) activities and toward compensated (incentivized) activities. Such behavior has been documented in a number of empirical studies. In a field experiment in Chinese factories, Hong et al. (2013) find that output increases but quality falls when a piece-rate bonus scheme is introduced. Glewwe, Ilias, and Kremer (2010) conduct a field experiment in which some teachers are paid on the basis of students' test scores. They find that teachers that receive the monetary incentive allocate more time to prepare students for the test situation, but there is little evidence that these teachers engage in more or better teaching of the subject. Bergstresser and Philippon (2006) show that CEOs whose compensation is more closely tied to the value of stock and option holdings engage in more short-term earnings manipulation. These CEOs also sell unusually large amounts of equity and options during years of positive earnings manipulation.

The multi-tasking model predicts that when some important task is hard to evaluate, then incentives should be weak for all tasks. Using data from the BLS Industry Wage Survey, Brown (1990) finds that incentive pay, such as piece rates, is common in jobs with a narrow set of routines. Jobs that involve a wide variety of duties more frequently pay a fixed salary. Since the latter kinds of jobs plausibly are the ones where workers can easily substitute one task for another, and where some important tasks are difficult to measure, these results provide at least indirect support for the multi-tasking model.

More direct empirical support for the multi-tasking model is found in Slade's (1996) study of contracting between oil companies and service stations. Service stations provide various services in addition to gasoline sales, such as car repairs and convenience store sales, and the substitutability of these activities varies. When the gas station also does car repairs, the oil company will worry that the service station will put too much effort into promoting its repairs business, and the model predicts the use of a more performance-sensitive contract for gasoline sales to mitigate this behavior. In contrast, this is not a problem when the side-business of the gas station is running a convenience store, since customers tend to take the opportunity to fill up their cars when they visit the convenience store (and vice versa). In this latter case, the model predicts a less performance-sensitive incentive contract for gasoline sales, since oil companies are better at carrying the risk of fluctuating sales. Slade (1996) indeed finds empirical evidence of more performance-sensitive contracts for gasoline sales when other service station activities are more easily substituted for selling gasoline (i.e., car repairs), and less performance-sensitive contracts when the other activities are complementary to selling gasoline (i.e., convenience stores), consistent with the multi-tasking model.

Incentives in Teams Many production processes require the cooperation of many agents. If it is only possible to measure aggregate output, it may be difficult to contractually provide optimal incentives for each agent, since there is an incentive to free-ride on the effort of others. The problem is that an individual agent who cheats by providing lower effort cannot be identified if joint output is the only indicator of effort. This is known as the "moral hazard in teams" problem, and the seminal paper on this is Holmström (1982a). Holmström shows that if the compensation to the agents involves sharing of some joint output, as in a partnership, the outcome will always be inefficient. In order to preserve incentives, a third party – a "budget breaker" – needs to be involved. The budget breaker can create incentives by removing output from the team in case of inferior performance. This provides a rationale for external ownership of firms by a residual claimant, as well as an explanation for why a firm needs to seek outside financing to be able to break its budget constraint.[22] Holmström (1999) discusses how to incorporate this insight into a more general theory of the firm.

Holmström (1982a) also highlights a potential benefit of teams in terms of writing incentive contracts, namely that aggregate team performance can be useful in filtering out noise in an individual agent's performance contract. That is, aggregate performance can be a useful signal of an agent's effort beyond the agent's individual performance, and should then (by the Informativeness Principle) be included in the optimal contract. In particular, if the output produced by different agents in a team is affected by the same external factors, then an agent's relative performance compared to the other agents in the team will be a more informative signal of the agent's individual effort compared to his absolute performance.

Career Concerns Agents who are concerned about their future careers may have an incentive to work hard even under simple fixed-wage contracts. Eugene Fama, the 2013 Economics Laureate, argued that career concerns might therefore solve moral hazard problems, without any need for explicit performance-based contracts (Fama, 1980). The idea of career concerns was formalized by Holmström (1982b).

To provide good incentives, the principal may want to promise high future salaries to agents who perform well today. But would such promises be credible? In Holmström's career-concerns model, an agent's performance today depends both on his effort and on his ability, and both are unobserved. A good performance today makes it more likely that the agent's ability is high, and this makes him more attractive not only to his current principal, but also to other employers. Competition for the agent's services then makes it perfectly credible that his future wage depends on his current performance. Thus, there will be an incentive to perform at a high level, even if contracts contain no explicit incentive schemes.[23]

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[22] Legros and Matsushima (1991) and Legros and Matthews (1993) show, however, that it is often possible to implement small deviations from the first-best action profile that allows the principal to identify cheating by an individual agent more easily. It is then possible to implement close to first-best effort with incentive schemes that always satisfy budget balance.

[23] Lazear and Rosen (1981) provide a different perspective on careers within organizations. In their model, the principal provides incentives by making a commitment to promoting the most productive worker to a higher position with higher pay. It may in fact be easier to commit to a promotion policy than to a pay-for-performance scheme, if promotions are verifiable to outsiders.

More formally, suppose there are two periods, $\tau = 1$ and $\tau = 2$. The agent's ability, denoted by θ, is the same in both periods. A key assumption is that θ is initially unknown to both P and A, and will be inferred from the first-period performance.[24] In each period τ the agent A chooses effort $a_\tau \in [\underline{a}, \bar{a}]$ and produces output $\beta_\tau = b(\theta + a_\tau) + \varepsilon_\tau$. Assuming that it is impossible to write explicit performance-based contracts, the period τ wage w_τ must be independent of β_τ. However, labor market competition ensures that w_2 will depend on β_1. Specifically, w_2 will equal the market's rational expectation about β_2, conditional on the realized β_1. Since the market will infer a higher ability when first-period output is higher, w_2 is increasing in β_1. Clearly, A has no reason to work hard in period 2 as his career is about to end, so $a_2 = \underline{a}$. In period 1, however, he has an incentive to build a reputation by producing a high output, thus convincing the market that his ability is high. Assuming for simplicity the agent is risk-neutral, he will choose a_1 to maximize $-c(a_1) + \delta E(w_2)$, where $c(a_1)$ is his cost of effort as before, and $\delta < 1$ is the discount factor.

The model confirms that career concerns may alleviate moral-hazard problems: since w_2 is increasing in β_1, and β_1 is increasing in a_1, the agent will set $a_1 > \underline{a}$ in order to raise $E(w_2)$. In fact, it is quite possible that a_1 exceeds the first-best level, although $a_2 = \underline{a}$ is clearly below first-best.[25] A key insight derived from Holmström's formalization of career concerns is that incentives will be unbalanced over time and equilibrium effort levels will in general not be socially optimal. Agents may well work excessively hard early in their careers (when career concerns are very strong), while effort will certainly be too low later on (when career concerns are weak or non-existent). If explicit performance-based contracts were possible, they might compensate for the latter inefficiency by providing explicit incentives for workers close to retirement (see Gibbons and Murphy, 1992). (For young agents with strong career-concerns, explicit incentive schemes may be redundant or even harmful.)

Holmström and Ricart i Costa (1986) apply the career-concerns model to a setting where the agent is a manager who makes an investment choice. In their model, young managers have an incentive to overinvest in order to signal their ability, and they show that rationing the manager's capital can be an optimal response to this behavior. They argue that this is consistent with the extensive capital-budgeting procedures observed in firms.

Important extensions of the basic career-concerns model include Stein (1989),

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[24] If there is asymmetric information, such that (only) A knows θ at the outset, the situation is more complex and invites signalling by A. However, most of the insights from the simple model continue to hold in a signaling equilibrium.

[25] If we simplify by assuming $\varepsilon_\tau \equiv 0$, then it is easy to show that a_1 will exceed the first-best if b is strictly concave and δ is close enough to 1. Intuitively, concavity implies that an increase in the market expectation about θ will have a very large impact on the expected second-period productivity, because $a_2 = \underline{a}$. This means that an agent who cares about the future (high δ) has a very big incentive to raise the market's beliefs about θ. Formally, rational expectations imply $dw_2/da_1 = b'(\theta + \underline{a})$ in equilibrium. The agent's first-order condition which determines his choice of a_1 is $-c'(a_1) + \delta E(b'(\theta + \underline{a})) = 0$. In contrast, the first-best is determined by the condition $-c'(a_1^*) + E\left(b'\left(\theta + a_1^*\right)\right) = 0$. Since b is strictly concave, δ is close to 1 and $a_1^* > \underline{a}$, we get $a_1 > a_1^*$. Of course, if δ were small then career concerns would be unimportant and $a_1 < a_1^*$.

Scharfstein and Stein (1990), and Dewatripont et al. (1999a, 1999b). The career-concerns model has also been used extensively in political economics and political science to model the behavior of career-motivated politicians, who care about re-election rather than future wages (see Lohmann, 1998, and Persson and Tabellini, 2000). In this application, some politicians are more productive than others, which voters appreciate. Observing an incumbent who produces good results, voters are more likely to re-elect him. This provides incentives for incumbent politicians to exert more effort, especially before an upcoming election, which may generate a "political business cycle".

In the career-concerns model, firms do not offer long-run contracts; rather, the wage is determined in each period based on the worker's expected output. What happens if firms can make long-run commitments, but workers cannot do so (i.e., workers are always free to quit)? Harris and Holmström (1982) develop such an "asymmetric commitment" model of labor contracts under incomplete but symmetric information, where each worker's productivity is revealed over time. They show that optimal dynamic risk sharing implies that wages should never decline over time, and only increase when the market increases its assessment of the worker's quality. This explains why earnings may be positively related to experience even after controlling for productivity. Although Harris and Holmström (1982) develop the model in the context of a labor market, the idea of asymmetric commitment is very important in many contexts, such as insurance markets, where information about an agent's characteristics is revealed over time (Hendel and Lizzeri, 2003).

Empirical Evidence on Career Concerns Empirical studies support the notion that incentives in organizations depend on both career concerns and explicit performance pay.[26] Gibbons and Murphy (1992) find that CEO compensation exhibits the most performance sensitivity for executives closer to retirement, consistent with explicit incentives being more important when career concerns are weaker. In fact, the combined use of implicit incentives through career concerns and explicit incentives through contracts could provide an explanation for the lack of indexation in contracts – i.e., for the apparent empirical failure of the informativeness principle, discussed above. It may be that relative performance evaluation is primarily implemented through promotion and firing decisions rather than through explicit contracts. Consistent with this idea, Morck et al. (1989) document that CEO turnover increases when a firm underperforms relative to its industry.[27]

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[26] An in-depth analysis of personnel and wage data from a single firm can be found in Baker, Gibbs and Holmström (1994a, 1994b). Their results indicate that promotions and performance pay are used jointly to provide incentives.

[27] Jenter and Kanaan (2015) and Kaplan and Minton (2012) show that CEO turnover is significantly related to (1) the performance of the firm relative to the industry, (2) the performance of the industry relative to the stock market, and (3) the overall performance of the stock market. Hence, it seems that external shocks are only partially filtered out, so that CEOs are still to some extent fired for bad luck. Kaplan and Minton (2012) propose an alternative explanation: when an industry or the overall economy performs poorly, it is efficient

Hong and Kubik (2000, 2003) provide evidence on the career concerns of security analysts. Hong and Kubik (2000) find that inexperienced analysts are more likely to "herd", i.e., they provide forecasts that deviate less from the market consensus. This is consistent with a multi-agent version of the career-concerns model (Scharfstein and Stein, 1990): inexperienced analysts have more to lose by being wrong, because there is more uncertainty about their ability, and therefore try to avoid "standing out from the crowd."

Hendel and Lizzeri (2003) consider a model with symmetric learning and asymmetric commitment, based on Harris and Holmström (1982), but applied to an insurance market instead of a labor market. With only short-run contracts, the consumer would be exposed to the risk of increased premiums if there is bad news about his health prospects. In contrast, if the insurance company can commit not to raise premiums, then long-run contracts will be "front-loaded": initial premiums will be fairly high, but they are lower later on. This locks in the consumers and provides dynamic insurance; agents whose health prospects deteriorate benefit by paying less. Hendel and Lizzeri find that the theory very successfully explains the shape and variety of existing life insurance contracts in the U.S. (which are indeed front-loaded).[28] Strikingly, there is an exception which proves the rule: there is no front-loading in accidental death contracts (which pay only if death is accidental), where learning about consumer characteristics should be much less of an issue.

3 Incomplete Contracts: Allocating Decision Rights

In this section, we discuss Oliver Hart's work on the theory of incomplete contracts. The first subsection presents the basic ideas of incomplete-contracts theory. Subsection 3.2 discusses the foundations of the theory, while Subsection 3.3 reviews some applications.

3.1 The Basic Ideas

Section 2 described the classic moral-hazard model, where contracting parties write performance-based contracts *ex ante* and enforce appropriate rewards *ex post*. However, we noted that measuring performance may be difficult. Even if performance can be evaluated *ex post*, it may be difficult to write a sufficiently detailed contract ex ante, specifying exactly what aspect of performance will be rewarded. Finally, even if such a contract could be written, it may be difficult to enforce it, because a third party (e.g., a judge) may not be able to verify the performance *ex post*. In view of the difficulties involved in writing and enforcing detailed contracts, it is not surprising that many of the contracts we actually observe are highly incomplete. This is the motivation behind the *incomplete contracts* approach to contracting, pioneered by Oliver Hart and his coauthors.

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to restructure the firm, which could require a different management team.

[28] The variety of existing contracts is explained by consumer heterogenity in willingness to front-load, which in turn can be explained by capital market imperfections.

Decision Rights and Property Rights A central insight in the incomplete-contracts literature is that carefully allocated decision or control rights can substitute for contractually specified rewards. Since an important means to allocate decision rights is through ownership, incomplete-contracting theory generates a rich theory of property rights. In the words of Hart (1989, p.1765):

> ownership of an asset goes together with the possession of residual rights of control over the asset; the owner has the right to use the asset in any way not inconsistent with a prior contract, custom, or any law.

In terms of the simple framework outlined at the beginning of Section 2, suppose it is impossible to contract directly on a transfer schedule $t(\beta)$. Transfers may instead be implemented indirectly through other kinds of contractual arrangements, notably through the assignment of ownership rights. Because risk-sharing plays no role, we drop the noise term ε.

Consider first an almost trivial case. The agent produces some output that has value $\beta = b(a)$ to P, but also has other uses. Let the value in the best alternative use be given by a differentiable function $v(a)$, where $0 < v(a) < b(a)$ and $0 < v'(a) < b'(a)$ for all $a \in [\underline{a}, \bar{a}]$. *Ex ante* (before A chooses a) the parties decide who will own the final output. In Section 2, P-ownership of the output was implicit. But if neither a nor β can be contracted on, under P-ownership A gets no share of β and therefore will set $a = \underline{a}$ in order to minimize $c(a)$. In contrast, with A-ownership of the output, A can deny P the output and get at least $v(a)$. But he can do even better by negotiating a trade with P after the output has been produced. If the two parties have equal bargaining power, the resulting transfer would be

$$t = v(a) + \frac{1}{2}\left(b(a) - v(a)\right) = \frac{b(a) + v(a)}{2}.$$

Anticipating this outcome, under A-ownership A chooses a to maximize $-c(a) + (b(a)+v(a))/2$. He will choose a bigger than $\underline{a}$ but smaller than a^*, so the surplus under A-ownership will be greater than under P-ownership, but less than in the first-best.

Incomplete Contracts and the Theory of the Firm The idea that contractual incompleteness implies a crucial role for property rights is quite general, and leads to a formal theory of the boundaries of the firm. The intellectual origin is 1991 Economics Laureate Ronald Coase's article on the theory of the firm. Coase (1937) argued that firms may organize certain transactions more efficiently than markets can. Unlike market transactions, most of the economic activity inside firms is not regulated by explicit contracts. 2009 Economics Laureate Oliver Williamson developed these ideas further and created a rich (albeit largely unformalized) theory of the firm based on incomplete contracts, known as transaction-cost economics (e.g., Williamson 1971, 1975, 1979, 1985).

Williamson initially emphasized *ex post* inefficiencies created by bargaining, but attention was later directed towards the incentives to make relation-specific investments ex ante. This became crystallized as the “hold-up problem”, explored in an influential article by Klein, Crawford, and Alchian (1978). The hold-up problem occurs when independent agents refrain from making adequate relationship-specific investments for fear of being “held up” and not getting a sufficient return on the investment. This provides a motive for integration. To explain why integration may not *always* be efficient, Williamson discussed possible inefficiencies caused by bureaucratic decision-making, but again the argument was largely unformalized. If firm size is limited by managerial attention, why is it not possible to integrate two firms while keeping managerial tasks all the same? Williamson (1985, ch. 6) does offer the plausible, if informal, argument that authority may be abused in order to facilitate inefficient transfers. But it was Grossman and Hart (1986) who developed a theoretical framework that captured both the costs and benefits of integration.[29]

An immediate implication is that there can be too much integration. With hindsight, this may seem like a very natural result, but the fact is that it had been much more difficult in the theory of the firm to give reasons for non-integration than for integration. Before Grossman and Hart first circulated their work, there was no convincing formal argument explaining why integration may have costs as well as benefits. In the words of Holmström (2015, p.2):

> The Grossman-Hart property rights theory is the first theory that explains in a straightforward way why markets are so critical in the context of organizational choice. The virtue of markets (nonintegration) is that owner-entrepreneurs can exercise their hold-up power. They can refuse to trade and go elsewhere. This right is a powerful driver of entrepreneurial incentives both in the model and in reality. Of course choice plays a critical role also in neoclassical models, but choice and hold-ups are never the drivers of organization.

Moreover, while transaction cost economics investigated the boundaries of the firm, Grossman and Hart (1986) took an important additional step: their model does not just predict where the boundaries of the firm should lie; it makes specific predictions about *who* should own a particular asset. In effect, ownership should be given to the party that makes the most important non-contractible investment. Nonintegration, i.e. both parties separately owning their assets, is optimal when the parties’ investments are equally important.

Ownership Structures and Investment Incentives Grossman and Hart (1986) studied how the incentives to make non-contractible investments depend on asset ownership. In their model, two firms, such as an upstream supplier and a downstream producer, must cooperate to produce a final good. Both parties make relationship-specific investments. Contracts are incomplete in the sense that the firms can contract neither on investment levels nor on the division of surplus. The incentive of each firm to invest in the relationship depends on its expectations about how the surplus will be shared, which in turn depends on the ownership of physical assets. Possible ownership structures are the supplier owning all assets (upstream vertical integration), the producer owning all assets (downstream vertical integration), or each firm owning its own assets (non-integration). The model incorporates several key components of the earlier transaction cost approach: incomplete contracting, relationship-specific investments, and hold-up. However, in the Grossman and Hart (1986) model, the costs and benefits of the various ownership structures are derived solely from their impact on relationship-specific investments; the theory assumes no *ex post* inefficiencies caused by bargaining or bureaucratic decision-making.

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[29] Grout (1984) provided the first formal model of underinvestment caused by hold-up. However, it was Grossman and Hart (1986) who first investigated how the consequences of hold-up vary with changes in the ownership structure, having made the key observation that ownership of an asset determines residual control rights.

To see how ownership of physical assets determines incentives with incomplete contracts, we return to the principal–agent framework. Suppose A's action a is an investment in human capital ("knowledge") which is needed for production to take place. (In this simplified example, P makes no investment.) To produce the output, some physical asset – a machine – is also necessary. If A does not have access to the machine, there can be no production. The crucial assumption is that whoever owns the machine decides who has access to it. That is, ownership comes with a veto right, and this will influence the terms of trade. If A owns the machine, it will strengthen his hand in negotiations with P, thereby increasing his share of the surplus. In turn, this increases A's incentive to invest in human capital.

If P owns the machine there is vertical integration; if A owns it there is non-integration. If P owns the machine, P has the right to refuse A's use of it. In this case, since both the machine and A's human capital are necessary for production to occur, let us assume A and P split the benefit $b(a)$ equally, so the transfer from P to A is $t = b(a)/2$. Thus, under P-ownership, A chooses an investment a_P which maximizes $b(a)/2 - c(a)$. Recall that the first-best a^* maximizes $b(a) - c(a)$. It follows that $a_P < a^*$; there is *underinvestment*.

Under A-ownership, A is no longer dependent on P to be able to produce, since A can unilaterally obtain $v(a)$ from the alternative use of the machine. Since $b(a) > v(a)$, we expect that P and A will still agree to trade, but now the terms could be more favorable to A. Intuitively, A's share of the surplus will be increasing in his outside option $v(a)$. Following Grossman and Hart (1986), assume the transfer from P to A will be

$$t = v(a) + \frac{b(a) - v(a)}{2}.$$

That is, the two parties split the difference between what they could earn on their own and what they can earn jointly. Thus, under A-ownership, A chooses an investment a_A to maximize

$$-c(a) + v(a) + (b(a) - v(a))/2$$

The solution satisfies $a_P < a_A < a^*$ so that A-ownership generates a greater surplus than P-ownership. Indeed, with A-ownership the transfer depends on A's outside option $v(a)$, which raises A's marginal return from investing. Regardless of ownership, however, in this simple example the investment will be less than the first-best level.[30]

Grossman and Hart's (1986) model is more symmetric than our simplified example: each party is endowed with an asset and makes an investment. Either each party maintains the property rights to its original asset (non-integration), or one party buys the other (integration). Either integration or non-integration may be optimal, depending on which ownership form has the most beneficial effect on investments. For example, if the assets are highly complementary, so having access to only one asset does not generate a higher marginal return on investment than having access to neither asset, then some form of integration is optimal (either P or A should own both assets); if having access to both assets does not generate a higher marginal return on investment than having access to just one asset, then non-integration is optimal.

However, the two-firm set-up of Grossman and Hart (1986) does not allow us to consider large corporations with multiple divisions, customers, and suppliers, and perhaps thousands of employees. Hart and Moore (1990) develop the property-rights theory for a multi-party, multi-asset setting, and also allow for a richer production framework, especially with respect to the complementarity between assets and between assets and people.

Multiple Parties, Investments and Assets For now, let us maintain the assumption that there are two parties, A and P, but now there are many productive assets and both parties invest in human capital. Let a and p denote A's and P's investment levels, respectively. Let $c_A(a)$ denote A's cost function, and $c_P(p)$ P's cost function. Let v_i denote the outside option of party $i \in \{A, P\}$, i.e., the payoff that party can unilaterally guarantee himself/herself if they separate (i.e., fail to cooperate). Finally, let β denote the benefit that P derives from cooperating with A.

Assuming $\beta > v_A + v_P$, cooperation is efficient. Since the theory assumes no *ex post* inefficiencies, the two parties are expected to cooperate. However, the outside options matter because they influence the transfer from P to A. Moreover, those options depend on the allocation of property rights, because if the parties separate then the party that owns an asset can prevent the other one from using it. Accordingly, transferring ownership of any particular asset from P to A will increase v_A and reduce v_P (but it will not influence β, since all assets will be used when A and P cooperate).

The transfer t is assumed to equalize the net gains from cooperation: $t - v_A =$

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[30] We get $a_A < a^*$ from the assumption that v increases slowly relative to b. If v instead increases fast in the relevant interval, A-ownership could lead to overinvestment and a lower surplus than P-ownership. For example, if A is tempted to overwork in order to attract lucrative outside offers (thereby bidding up the wage), it could be better to reduce that temptation by letting P own crucial assets.

$\beta - t - v_P$. Solving for t we get that

$$t = \frac{1}{2}\left(\beta + v_A - v_P\right).$$

A will choose a to maximize his payoff

$$\pi_A = t - c_A(a) = \frac{1}{2}\left(\beta + v_A - v_P\right) - c_A(a)$$

while P will choose p to maximize her payoff

$$\pi_P = \beta - t - c_P(p) = \frac{1}{2}\left(\beta - v_A + v_P\right) - c_P(p)$$

If the parties do not cooperate, they cannot benefit from the other party's human capital, so v_A is independent of p, and v_P is independent of a. The incentives to invest therefore depend on the derivatives

$$\frac{\partial \pi_A}{\partial a} = \frac{1}{2}\left(\frac{\partial \beta}{\partial a} + \frac{dv_A}{da}\right) - \frac{dc_A}{da} \tag{9}$$

and

$$\frac{\partial \pi_P}{\partial p} = \frac{1}{2}\left(\frac{\partial \beta}{\partial p} + \frac{dv_P}{dp}\right) - \frac{dc_P}{dp} \tag{10}$$

The allocation of property rights influences these derivatives (only) via its effect on the outside options v_A and v_P. It is reasonable to assume that, if a party can use more assets after separation, its human capital has a bigger effect on its separation payoff. In this case, transferring ownership of any asset from P to A raises $\frac{dv_A}{da}$ but reduces $\frac{dv_P}{dp}$ and thus, from (9) and (10), raises A's incentive to invest but reduces P's incentive to do so. This immediately reveals the crucial trade-off: one party's incentive to invest can be increased by giving him or her ownership of more assets, but then the incentive of the other party must necessary be reduced.[31] Moreover, as long as there is underinvestment in equilibrium, the first effect raises the surplus but the second effect reduces it; thus, the trade-off also applies to surplus calculations.

In the special case of two parties, Hart and Moore's (1990) results can essentially be obtained from (9) and (10). If one party's investment becomes more important (in terms of raising the benefit β), then this party should own more assets. Indeed, in the limiting case where only one party's investment matters, this party should own all assets. Hart and Moore (1990) also conclude that joint ownership is inefficient, because if each party can hold up the other party (deny him or her the use of the asset after separation), incentives are weakened for both parties. For the same reason, strictly complementary assets should be owned together. Outside ownership is always inefficient, since the outsider can deny both parties the use of the asset.

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[31] However, if one party is indispensable for some asset to be of value, then there is no trade-off, and this party should always own this asset.

With $n > 2$ parties, Hart and Moore (1990) use the Shapley Value, due to 2012 Economics Laureate Lloyd Shapley, to derive the *ex post* division of surplus (Shapley, 1953). This allows them to predict a rich variety of ownership structures, contingent on who the "key actors" are. For example, suppose J workers work with a single asset to supply a service to K consumers. If there is a group $G \subset J$ of "key workers" such that any worker's marginal product of investment is positive only if he is a member of a coalition that contains a majority of the members of G, then the optimal ownership structure is a partnership – decisions should be made by majority vote among the members of G.

Empirical Tests of the Property-Rights Theory A key aspect of the property-rights approach of Grossman and Hart (1986) and Hart and Moore (1990) is that it is possible to increase one party's incentives to make non-contractible investments (by giving this party ownership of more assets) only at the cost of reducing another party's incentives. Therefore, the party whose non-contractible investments are more important should own more assets. Testing this prediction requires a convincing measure of non-contractible investments (as opposed to overall investments). Acemoglu et al. (2010) propose that "technology intensity" may serve as a reasonable proxy. In their study of UK manufacturing industries (where the downstream firm is often the largest), they investigate how backward integration depends on the technology intensity of manufacturers. As predicted by the property-rights approach, they find that upstream integration by manufacturers is an increasing function of the manufacturer's technology intensity and a decreasing function of the supplier's technology intensity.[32]

Other empirical regularities that support the property-rights approach to vertical integration come from ownership of retail outlets. Woodruff's (2002) detailed study of the Mexican footwear industry is a good illustration. In segments where fashion changes fast, retailers are more likely to own their shops than in segments where fashion is more stable. Woodruff argues that this happens because in the fast-changing segment retailers have a crucial role in ordering and displaying the shoes that are most likely to attract customers, and this is an activity that is difficult to contract on.[33] For another example, ownership of gasoline stations is more likely to rest with the station manager if the station offers car repairs, the quality of which is difficult to observe and contract on (Shepard, 1993).

A possible difficulty in interpreting these and similar studies is that in reality the agents take multi-dimensional and interdependent actions. For example, car repairs may divert attention from serving customers at the gasoline pump, so perhaps ownership is granted to the manager in order to create balanced incentives. If this is the case, the ownership patterns among gas stations may be better explained by the multi-tasking model of Holmström and Milgrom (1991). But comparing the explanatory power of the models is difficult, as noted by Lafontaine and Slade (2007), because each seems to capture important aspects of reality. For example, Baker and Hubbard (2003, 2004) argue that the organization of the U.S. trucking industry is best explained by a combination of the property-rights model and the multi-tasking model.

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[32] Other work that exploits the incomplete-contracting model to address data on aggregate ownership patterns includes Antras (2003), who studies the choice between integration and outsourcing, using data on multinational corporations.

[33] Here, then, is another case in which more risk goes together with stronger incentives.

3.2 Theoretical Foundations for Incomplete Contracts

The theory of incomplete contracts has been criticized for making seemingly strong, and perhaps rather arbitrary, assumptions – see especially Noldeke and Schmidt (1994), Tirole (1999), and Maskin and Tirole (1999). This critique stimulated theorists to develop a variety of micro-foundations for contractual incompleteness, including Anderlini and Felli (1994), Hart and Moore (1999), Segal (1999), and Tirole (2009).

In Section 3.1, we mentioned a possible reason for contractual incompleteness: many variables (such as investments, costs, benefits or market conditions) are not verifiable to outsiders, although they may be observed by the contracting parties themselves (Grossman and Hart, 1986). However, an early criticism of the incomplete-contracts theory was that information about such variables could, in theory at least, be elicited from the contracting parties by using "message games" (as described in Maskin, 1977). In turn, this would make it possible to write contracts contingent on variables that are observed but not verifiable. Such contracts could implement first-best investment levels regardless of ownership structure, thus challenging the theoretical validity of the property-rights approach. Hart and Moore (1988) addressed this point in a buyer-seller problem similar to Grossman and Hart (1986). At time 0, the two parties sign a contract, then they make (unverifiable) relationship-specific investments. At time 1, benefits and costs are realized; this information is observed by the two parties but unverifiable. Finally, at time 2 trade may occur. In contrast to Grossman and Hart (1986), Hart and Moore allow message games to elicit unverifiable information at time 1, and time 2 actions are contractible. However, they introduce one crucial, but plausible, restriction on the contracts: the parties cannot commit not to renegotiate the contract at time 2. Under this restriction, they find that the first-best investment levels cannot in general be implemented, and that the optimal contract may in fact be a simple pair of prices that more complex message games cannot improve upon. Remarkably, very simple contracts turn out to be "as complete as possible".

Hart and Moore's (1988) approach was quite novel and, although they did not stress the issue of control rights, they in fact strengthened the foundation of the property rights approach. Methodologically, they showed how a mechanism-design approach, which until then had been quite abstract (as in Maskin, 1977), produces less abstract results when renegotiation is added. This methodology was adopted by much of the subsequent literature, although the precise Hart and Moore (1988) results turned out to be sensitive to their assumptions. In particular, they assumed outsiders cannot observe whether the seller has delivered the good to the buyer. Noldeke and Schmidt (1994) showed that if this assumption is dropped, then the first-best can be attained (using simple "option contracts"). On the other hand, in variations of the Hart and Moore (1988) model the original results are more robust. Che and Hausch (1999) assume the investment of each party has an externality on the other party: the seller's investment would affect the buyer's benefit, and the buyer's investment would affect the seller's cost. They show that if those externalities are sufficiently important, and if the parties cannot commit not to renegotiate the initial contract, then the first-best cannot be implemented. The optimal solution is in effect to have no contract at all.

Contractual incompleteness could also be due to the impossibility of describing all possible future contingencies (market conditions, states of nature etc.) in advance; there are too many possible contingencies to describe, or even to foresee. However, Maskin and Tirole (1999) show that as long as the parties can foresee the possible *payoffs*, the first-best can be implemented by a message game which does not require describing all possible contingencies in advance. They argue that parties that are sufficiently rational to calculate the expected payoffs from an incomplete contract should also be able to use the effectively complete contracts they propose. In a rejoinder, Hart and Moore (1999) show that Maskin and Tirole's first-best investment result can be overturned in a sufficiently complex contracting environment (borrowed from Segal, 1999), when parties cannot commit not to renegotiate the initial contract. Furthermore, Aghion et al. (2012) demonstrate that some of the objections to the incomplete-contracts framework are fragile, in the sense that the more complete contracts proposed in the critique only perform well under very strong common-knowledge assumptions.

It is fair to say that the debate regarding the theoretical foundations of incomplete contracts is not yet settled. This debate has nevertheless yielded considerable insights regarding the importance of limited commitment, complexity, and cognitive limitations for the incomplete contracts we observe in reality. The fact remains that in reality we do not observe the sophisticated mechanisms (e.g., message games) that would circumvent incomplete contracting; real-world contracts are often highly incomplete, with allocation of control and property rights playing a central role. Perhaps the behavioral assumptions of standard economic theory warrant closer investigation.

In recent work, Hart has in fact moved beyond the standard behavioral assumptions. In Hart and Moore (2008) and Hart (2009), the *ex ante* contract shapes parties' entitlements regarding *ex post* outcomes. If a party does not get what she feels entitled to, she is aggrieved and will "shade" her performance *ex post*, causing dead-weight losses. For example, if the *ex post* contracting outcome is worse than the agent expected given the initial contract (i.e. the "reference point"), she might choose to deliver a product of inferior quality. The *ex post* shading cannot be undone through bargaining, and so (unlike in the original property-rights theory) outcomes can be *ex post* inefficient. This approach yields a trade-off between rigid and flexible contracts: a flexible contract is good in that parties can adjust to the state of nature, but bad in that there can be a lot of aggrievement and shading. Moreover, unlike models based on standard rationality assumptions and efficient *ex post* bargaining, this model is not subject to the Maskin and Tirole (1999) critique. Hart and Moore (2008) use their model to explain employment contracts, where the wage is fixed in advance and the employer chooses the employee's task. In subsequent work with Holmström, Hart uses this model to revisit the problem of the boundaries of the firm and the costs and benefits of integration (Hart and Holmström, 2010).

The behavioral assumptions underlying these new models are non-standard. However, laboratory experiments by Hart and coauthors provide empirical evidence supportive of shading behavior consistent with this modelling approach (Fehr, Hart and Zehnder, 2009, 2011 and 2015).

3.3 Applications

Privatization and Public versus Private Ownership The property-rights framework helps us understand the costs and benefits of privatization and public versus private ownership (Schmidt, 1996, and Hart, 2003). In a complete-contracting model, public or private ownership does not matter, since the relationship between the government and a firm can be fully resolved in a detailed incentive contract. By contrast, when contracts are incomplete, the identity of the owner becomes highly relevant, because the owner retains the residual rights of control. In the context of our illustrative model, let P be the government who desires the production of some public service, and let A be a manager in charge of producing this service. As usual, the ownership of assets will affect bargaining power and incentives. In the context of privatization, the government cares about production efficiency as well as quality of service. But the quality of welfare services, say, may be hard to specify in a contract, while the private contractor has an incentive to produce at lowest cost.[34]

In an influential article, Hart, Shleifer, and Vishny (1997) study privatization by combining the incomplete-contracts approach with the multi-tasking model of Holmström and Milgrom (1991). Let us illustrate a special case of their approach in our simple model. Suppose an innovation would reduce both costs and benefits. The asset owner has the right to implement the innovation or to prevent its implementation. As before, actions are not contractible.

To be specific, suppose the innovation reduces P's benefit from b_0 to $b_0 - z(a)$ and reduces A's cost from c_0 to $c_0 - m(a)$. Here $z(a)$ and $m(a)$ are both increasing in a, where $a \in [\underline{a}, \bar{a}]$ is interpreted as a cost-saving but quality-reducing activity of the agent.[35] Assume that the innovation is efficient: implementing it raises the total surplus by the positive amount $m(a) - z(a) > 0$ for all $a \in [\underline{a}, \bar{a}]$. Further, the first-best occurs at an interior point $a^* \in (0, \bar{a})$ that satisfies the first-order $m'(a^*) = z'(a^*)$. That is, the gain from cost saving must be traded off against the loss from quality reduction.

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[34] Laffont and Tirole's complete-contracting analysis of these types of conflicts in government procurement was acknowledged in the 2014 Economics Prize to Jean Tirole.

[35] Note that, unlike our other examples so far, P's benefit and A's cost are decreasing in a.

Under A-ownership, A does not need approval from P to implement the cost-saving innovation. A will therefore reduce costs as much as possible in order to maximize $-c_0 + m(a)$. That is, he sets $a = \bar{a}$. Intuitively, since A can unilaterally implement the cost-reducing innovation, he has no reason to hold back and take P's quality concerns into account. The outcome becomes highly inefficient.

Under P-ownership, A's cost is c_0 unless he gets P's approval to implement the innovation. As before, let us assume that negotiations between A and P lead to an equal split of the increased surplus, which here equals $m(a) - z(a)$. Since A's payoff will be $-c_0 + (m(a) - z(a))/2$, he has the right incentives to trade off costs against quality, because A will maximize his payoff by choosing a^* such that $m'(a) - z'(a) = 0$. It follows that P-ownership is efficient. Intuitively, when P has the right to refuse the innovation, A must take P's interests into account.

However, Hart, Shleifer, and Vishny's model is more general than this simplified setup: they assume the agent can make two different types of innovations: cost innovations as well as quality innovations. A government-owned (P-owned) service provider will have little incentive to invest in either innovation, while a private contractor will have stronger incentives both to improve quality and to reduce costs. But they show that the private contractor's incentive to engage in cost reduction is typically *too* strong. In general, the greater the adverse consequences of (non-contractible) cost-cutting on (non-contractible) quality, the stronger is the case for government ownership.

This analysis offers a rigorous argument in favor of the view that outsourcing and privatization can be harmful because of excessive cost reduction and concomitant quality reduction, an argument that is difficult to articulate coherently in the case of complete contracts (where incentives can be fine-tuned). Recently, concerns about inefficiently low quality have been voiced in the context of the privatization of welfare services, such as schools, hospitals, and prisons. While competition may wholly or partly mitigate the problem for hospitals and schools, it might be more difficult to see what would do so in the case of prisons.

Corporate Finance The most important application of incomplete-contracts theory to date is in the field of corporate finance. Traditionally, financial contracts were seen as devices for furnishing investment capital and sharing risk. With agency theory, the emphasis changed. Economists came to see what many practitioners and legal scholars had seen all along, namely that a major purpose of financial contracting is to ensure that entrepreneurs and managers act in the interests of investors. Perhaps this is the greatest moral-hazard problem of all, at least in the business sector.

The first principal-agent models of corporate finance assumed complete contracts: Jensen and Meckling (1976) is generally regarded as the pioneering model. These authors show that if entrepreneurs' and investors' interests are not well-aligned, it is natural to give debt claims to investors and equity claims to entrepreneurs – who will then hold residual *cash flow* rights. Hart himself contributed to this literature in Grossman and Hart (1982), which shows how debt helps disciplining management to make more productive investments. These are important insights, but the framework does not address some crucial questions: who should hold the residual *control rights*, i.e. the right to make decisions that are not explicitly decided in an *ex ante* contract, and what happens to the allocation of these decision rights when a firm defaults on its debt?[36]

In reality, when an entrepreneur or a manager defaults on a payment to investors, claims are rarely automatically executed according to a complete contract. Instead, the default initiates a procedure to resolve the issue, where different parties hold other control rights than they did before the default. The entrepreneur (or the shareholders, in the case of widely owned firms) usually holds most control rights over the firm's physical assets before a default. But after a default many control rights are transferred to investors. In particular, the ownership of collateral shifts to the respective debt holders, who may eventually initiate liquidation of these assets.

More generally, corporate securities are characterized not only by their cash-flow rights – e.g. debt gets paid first, and equity receives the residual profits – but also by their control rights. Apart from required interest and amortization payments, debt contracts contain different covenants that the borrower needs to adhere to, such as minimum profitability requirements, as well as the right to veto certain actions, such as asset sales or new debt issues. These covenants effectively transfer more control to creditors when the firm performs poorly, even outside of bankruptcy (see Nini et al., 2012). In contrast, shareholders retain most control rights when the firm performs sufficiently well. In particular, equity securities are allocated the voting rights at the annual shareholders' meeting, which elects the board of the company and votes on major corporate decisions. The division of control rights between different securities can sometimes be very intricate, for example in the case of A and B shares with different voting rights observed in many firms, or the convertible preferred securities used in venture capital financing, as discussed below.

The power of the incomplete-contracts approach is that it explains why contracts have these general features to begin with, who will get to hold which rights, the nature of the renegotiation process, and the interaction between the allocation of cash-flow rights and control rights. With the introduction of contract incompleteness, it becomes obvious that corporate-finance decisions and corporate governance are inextricably linked. We cannot in general analyze the sharing of financial returns without at the same time analyzing the allocation of decision rights and other conflict-resolution procedures.

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[36] Another way to express this shortcoming of the complete-contracting explanation of capital structure is that one could achieve the same outcome simply by writing a compensation contract with the manager, without the use of equity and debt. An obvious benefit of this would be that the firm would never have to default on its debt and go bankrupt. See Hart (2001).

Finance and Governance of Entrepreneurial Firms In a paper originally circulated in 1989, Oliver Hart and John Moore address several of these issues.[37] The analysis turns on the concept of foreclosure rights and the role that they play in forcing entrepreneurs to repay their investors. More specifically, Hart and Moore consider an entrepreneur who may divert project returns, but cannot divert the firm's productive assets. Under some additional assumptions, the optimal (incomplete) contract has the following features (Hart and Moore, 1998, p.2):

> The entrepreneur promises to make a fixed stream of payments to the investor. As long as he makes these payments, the entrepreneur continues to run the project. However, if the entrepreneur defaults, the investor has the right to seize and liquidate the project assets. At this stage the entrepreneur and investor can renegotiate the contract.

These features bear a striking resemblance to real-world debt contracts. Also, the model provides an explanation for why firms can be credit-constrained, since their ability to raise finance is limited by the firm's collateral, or liquidation value. Finally, like Grossman and Hart (1986) and Hart and Moore (1990), it highlights the importance of control rights to physical assets.[38]

Aghion and Bolton (1992) was an important early application of the incomplete-contracting approach to financial contracting – the first published article featuring state-contingent transfer of control. However, in their model, the shift in control from the entrepreneur to investors is not directly associated with payment default, which is what we observe in real-world contracts (but rather with bad states of nature). Hart (2001) argues that one way to make control shifts happen upon bad performance is to introduce effort provision into the Aghion-Bolton model. Although the Hart and Moore model derives an optimal contract that captures more real-world features of debt, the Aghion–Bolton model has been useful in understanding security design in broader contexts, such as venture capital financing.[39]

Hart and Moore (1994) derive a very similar debt contract to Hart and Moore (1989, 1998) under the alternative (and less extreme) assumption that the manager can only divert her human capital – i.e., leave the firm and possibly start a new one – but not divert cash flows. Since the manager's firm-specific human capital is valuable, however, the value of the firm without the manager will restrict the amount of financing outside investors are willing to provide, and lead to a similar collateral constraint as the model with diversion. The model also predicts that longer-lived assets should to be financed by longer-maturity debt, which has been verified in empirical studies (see e.g. Benmelech, 2009).

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[37] The finished product was eventually published as Hart and Moore (1998) and – to some extent – Hart and Moore (1994), having by then inspired important contributions from others.

[38] The notion that the ability of the entrepreneur to divert cash flows can give rise to debt as the optimal contract was first formalized by Townsend (1979), and later extended by Gale and Hellwig (1984), in the context of complete contracts. However, their so-called costly state-verification approach does not address the crucial feature of state-contingent transfer of control rights or the importance of physical collateral. Bolton and Scharfstein (1990) also derived debt as an optimal contract in a setting where managers can divert cash flows. Their model has two periods and does not rely on collateral value or state-contingent transfer of control. Rather, management is restrained from diverting cash flow in the first period through the value of second-period profits, which they will only enjoy if they do not default and instead refinance their initial debt.

[39] Dewatripont and Tirole (1994) also derive the specific allocation of both cash-flow rights and control rights. Their model explains the coexistence of two separate outside investors in addition to the manager, debt and outside equity, and why outside equity relinquishes control to debt in the bad state of the world.

The models of Hart and Moore (1989, 1994) also rationalize the troubling fact that renegotiation and bankruptcy frequently lead to inefficient liquidation, in the sense that assets are transferred away from the entrepreneur who can extract most value from them. Since the entrepreneur cannot credibly pledge all future returns, external investors may be better off taking everything they can lay their hands on now, rather than leaving assets in the entrepreneur's hands and getting "a smaller share of a bigger pie" later.

Again, contractual incompleteness is crucial to these results. It is the fact that outside parties cannot verify several of the variables of interest – such as project returns and liquidation values – that precludes more efficient arrangements.

Evidence from Venture Capital Financing Kaplan and Strömberg (2003, 2004) report evidence from a large number of venture capital (VC) contracts. This is a real-world setting that quite closely corresponds to the environment of the financial contracting theories, where entrepreneurs who raise money for start-ups are the agents, and VC investors who invest in start-up firms are the principals. They find that VC financial contracts separately allocate cash-flow rights as well as different control rights – including board rights, voting rights, and liquidation rights – between investors and entrepreneurs. The allocation of these rights is frequently state-dependent, being contingent on financial as well as non-financial measures of performance. Both cash-flow and control rights are allocated such that investors obtain full control of poorly performing firms. But entrepreneurs retain more control rights in better performing firms, and their cash-flow rights increase with firm performance, often in a non-linear fashion.

Moreover, the allocation of rights responds to the perceived risk investors see in the venture, as well as the likelihood that investors will have to intervene in the future, for example by replacing management. Kaplan and Strömberg argue that these contracts can best be understood through a combination of incomplete-contracts theory and classic contract theory. Importantly, the separate allocation of cash-flow and control rights cannot be fully understood outside an incomplete-contracting framework.

Finance and Governance of Widely Held Firms Hart and Moore (1995) shift the focus from entrepreneurs to publicly held companies. In this work, managers (or company boards) take decisions that affect many dispersed claim holders. The managers, whose stake is usually small, may want to expand investment beyond the level that maximizes returns. To avoid this, investors need to achieve two things. First, they must force managers to pay out any excess liquidity to investors, e.g., through increased dividends or repurchases of stocks. Second, they must make sure that managers do not compensate for such payouts to shareholders by raising debt.

The article goes on to show that these twin objectives can be attained through two commonly observed financial instruments. Specifically, non-negotiable short-term debt accomplishes the first objective, while senior long-term debt accomplishes the second. The seniority of long-term debt claims ensures that new investors are reluctant to lend short-term, as they will hold junior claims in a bankruptcy.[40] Hart and Moore's model also entails realistic predictions concerning firms' debt-equity ratios in a framework where these contracts are optimal, i.e., without making the arbitrary assumption that debt and equity are the only available financial contracts. In an extension of the Hart-Moore model, Shleifer and Vishny (1992) provide an explanation for why inefficient fire-sales of assets happen in industry downturns.

We may mention here some related and influential work which preceded the development of the incomplete-contracting framework. Since Manne (1965), corporate-governance scholars have acknowledged the important role of hostile takeovers in disciplining self-interested management. If a manager underperforms – e.g., by not providing enough effort or diverting resources from the company – a more efficient corporate raider will acquire the firm and replace the management. This gives the manager incentives to perform well, in order not to be replaced by the corporate raider. However, Grossman and Hart (1980) showed how the allocation of control rights to shareholders of widely held and publicly traded firms may lead to a free-rider problem in corporate takeovers. A small shareholder, who would not expect to be pivotal to the success of a hostile takeover bid, has an incentive not to sell their stock to the hostile bidder. Rather, such a shareholder would rather stay on as a minority shareholder to enjoy the takeover gains the hostile bidder will realize. In the equilibrium with atomistic shareholders, all shareholders will behave in this way, and the raider will not be able to acquire the firm unless she offers a premium equal to the full gains from the takeover.[41] Unless the raider has some additional mechanism of extracting value from other shareholders, hostile takeovers will not occur, and so the power of this disciplining mechanism is limited.

Grossman and Hart (1988) extended the analysis by considering separate contracting on control rights. Suppose that residual control rights can be separated from residual cash-flow rights, for example by the firm issuing A and B shares with different voting rights. This could potentially alleviate the free-rider problem, since the raider only has to acquire the strong voting shares to take control of the firm. Strikingly, they found that the efficient solution is typically still to have one class of shares, namely a "one share, one vote" share structure.

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[40] In a sense, their theory combines two important concepts in corporate finance research – the debt overhang problem of Myers (1977) and the "free cash-flow problem" of Jensen (1986) – and shows how the former can be a solution to the latter.

[41] Holmström and Nalebuff (1992) extend the Grossman–Hart analysis to the case of non-atomistic shareholders.

Deviations from this voting structure would allow less efficient raiders to take control of the firm.

Bankruptcy Reform and Investor Rights Through its emphasis on which stakeholders have the right to do what under what circumstances, the framework of incomplete contracts allow us to sensibly talk about more or less efficient procedures for resolving conflicts of interest between entrepreneurs and investors, and thus about bankruptcy legislation. Building on his foundational contributions, Hart has studied empirically the inefficiencies of debt enforcement around the world (Djankov et al. 2008). He has also offered a number of suggestions for bankruptcy reform, as well as reform of financial institutions more broadly (e.g., Aghion et al., 1992; Hart et al., 1997; Hart and Zingales, 2011). More generally, the incomplete-contracting framework is now central to the analysis of corporate governance (see e.g. Shleifer and Vishny, 1997), and there is now considerable empirical work showing the importance of property rights and investor protection for financial market development (see, e.g., La Porta et al., 1997, 1998).[42]

Other Extensions and Applications The basic idea of assigning property rights in order to provide incentives has been elaborated in several other directions, of which we will mention a few. Bolton and Whinston (1993) analyze vertical integration in the presence of multiple potential trading partners.[43] Grossman and Helpman (2002) develop a general-equilibrium model in which there is a non-trivial interaction between the integration decisions of different firms in the same industry. Antras (2003) and Antras and Helpman (2004) consider international outsourcing, a setting in which it is especially difficult to enforce complete contracts, owing to diverging national rules and possible discrimination of foreign claim holders.

Besides the issue of asset ownership, the incomplete-contracts approach has been used to study the allocation of decision rights within the firm. This work concerns the optimal delegation of authority (Aghion and Tirole, 1997), as well as the separation of ownership and control (Burkart et al., 1997). In the highly cited Aghion and Tirole (1997) model, delegating tasks increases the initiative of the agent at the cost of less principal control. One implication of this model is that delegation increases the agent's incentive to collect and use soft decision-relevant information, which cannot be credibly transmitted up in the hierarchy in a less delegated structure. A number of empirical studies have found support for this prediction, e.g., by looking at reliance on soft versus hard information in bank-lending decisions (e.g., Berger et al., 2005 and Liberti and Mian, 2009).

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[42] The focus on governance rather than the mere division of surplus has served to build solid bridges between economists and legal scholars. Several of Hart's more applied contributions are published in law journals, and he has served as President of the American Law and Economics Association.

[43] Using an alternative approach, Hart and Tirole (1990) study vertical integration in a setting with limited commitment caused by the possibility of secret contracting. Their model shows that exclusionary practices by upstream or downstream firms, although privately rational, may have negative welfare effects.

In property-rights models of Hart and coauthors, decision rights over physical assets are the crucial source of bargaining power and incentives. But modern firms are frequently highly dependent on intangible assets, such as unique capabilities or intellectual property, and firms sometimes lack substantial physical assets. Rajan and Zingales (1998, 2001) consider a model where agents derive power from being able to regulate access to the firm's critical resources, which could be intangible assets, and use this to derive predictions about ownership patterns and the internal organization of firms.

One challenge has been to extend the property rights model of firms to more general settings, with richer possibilities for providing incentives than merely through decision rights. Assets are usually held by firms rather than individuals, and firm owners use rights to the whole bundle of assets to structure internal relationships, by means of task assignment, monitoring, and incentive contracts. Along these lines, Holmström (1999) attempts to integrate incomplete contracts with classic incentive theory in a richer model of the firm.[44]

All the applications above address central issues in the theory of the firm. But the incomplete-contracts model also has important applications to political institutions. For example, the division of responsibilities among different decision-making bodies – such as executive and legislative branches of government – can be productively viewed as an allocation of control rights along the same lines as in the theory of incomplete contracts (Persson et al., 1997; Aghion and Bolton, 2003; Aghion et al., 2004; Harstad, 2005).

4 Other Contributions

Before his focus shifted to contract theory, Oliver Hart contributed to a number of different areas, producing one or two highly influential articles on a topic before moving on to different territory. Early in his career, he worked on general equilibrium with incomplete markets. Hart (1974) considered the existence of incomplete-markets equilibrium and showed that in general, existence is not guaranteed. This inspired research on the conditions under which, generically at least, an equilibrium would exist. Hart (1975) considered the optimality properties of incomplete-markets equilibrium, and proved another result of lasting importance: making the market more complete, but not fully complete, by opening new markets, does not necessarily lead to Pareto improvement. Hart's work on monopolistic competition (in particular, Hart 1979 and 1982) inspired a significant literature on the role of imperfect competition in product markets as an explanation for Keynesian unemployment. Among Hart's early work on contract theory, we may highlight two contributions. The first is Grossman and Hart's (1983b) work on adverse selection in labor markets, which shows how underemployment can result from an optimal contract between a firm and its workers. The second, and highly influential contribution, is Hart (1983). In this article, Hart asked if competition in the product market can alleviate managerial incentive problems: that is, does more competition make it harder for managers to deviate from profit maximization? He found an affirmative answer under the assumption that firms are exposed to common shocks. However, in general this turns out to be a very difficult question to answer, and this is still an active research area more than 30 years after Hart's pioneering article.

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[44] Holmström's arguments rely partly on the "moral hazard in teams" problem, analysed in Holmström (1982a).

Bengt Holmström is best known for his work on contract theory and the theory of incentives, much of which we have already discussed. In recent years, he has studied issues relating to financial market liquidity and its relevance to financial regulation. Holmström and Tirole (1997, 1998, 2000, 2001, 2011) use a model of managerial wealth constraints to investigate a number of important issues in corporate finance, including the impact of wealth shocks on the banking system, banking regulation, the role of public liquidity provision for firms, and how liquidity affects asset prices and expected returns. Recently, Holmstrom has also explored the trade-off between financial market transparency and market liquidity (e.g. Dang et al., 2015).

5 Final Remarks

Contract theory identifies a variety of obstacles to cooperation and suggests which contracts are best suited to overcome them. The theory is both positive and normative: it offers coherent explanations for the contracts that are commonly written, as well as a method for finding appropriate contractual solutions to new problems. It generates precise hypotheses that can be confronted with empirical data and lays an intellectual foundation for the design of various policies and institutions, from bankruptcy legislation to political constitutions.

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