The essence of the hidden action problem is the conflict of interests between the principal and the agent, and an information asymmetry. The agent knows more than the principal and can use this superior information at the expense of the principal. These problems are anticipated by the principal, and this will be reflected in the contractual terms offered to the agent in order to discourage undesirable behaviour by the agent.

Two types of solutions for hidden action problems will be addressed. They are in line with the ingredients of the hidden action problem. The first solution entails changing the payoffs in order to reduce the conflict of interests. Payoffs in the contract will be structured in such a way that the interests of the principal and the agent are better aligned. The second solution concerns changing the information structure. The principal will try to gather additional information in order to reduce the information asymmetry. A third possible solution for the hidden action problem is changing one of the players, i.e. the principal or the agent. This solution will not be treated in a separate section, because it is on the one hand straightforward and on the other has some features which are addressed in Chapter 7.

Section 6.1 explains the effect of the information structure on the nature and design of meaningful contracts. Reducing the conflict of interests by the design of the contract is addressed in Sec. 6.2. Section 6.3 highlights a situation in which the agent performs several tasks. Including additional information in the contract in order to reduce the information asymmetry is the topic of Sec. 6.4. The nature of the firm is addressed from a complete contracting point of view in Sec. 6.5. Section 6.6 concludes.

6.1 Contract design

The use of performance stimuli in contracts in order to reduce the conflict of interests between principal and agent will be introduced with a numeral example. First, the situation of complete information is outlined. Second, the effect of asymmetric information on the design of the contract is examined in the same example. The analysis is based on Milgrom and Roberts (1992).

6.1.1 Complete information

Suppose that the payoff of the agent equals $\sqrt{w} - e$, where $\sqrt{w}$ is the valuation of the salary w by the agent and e the level of effort of the agent. The payoff of the principal is $P(e) - w$, where $P(e)$ is the value of output when the level of effort provided by the agent is e. A higher level of effort will increase the level of output. Assume that the opportunity costs of the principal are 0 and the opportunity costs of the agent are 1. The specification reflects the conflict of interest between the principal and the agent, because a larger effort increases the level of output for the principal, but it reduces the payoff of the agent by the additional costs of providing this higher level of effort.

The payoff $P(e) - w$ of the principal reflects *risk-neutrality*, because the payoff function is linear in w, i.e. a payoff with certainty is valued as high as an uncertain payoff which is on average the same. This is often representative for the principal, because the principal is usually a company or a person who handles many other projects as well. Risks can therefore be spread, i.e. uncertainty regarding specific projects has little influence on the average results of the entire portfolio of projects.

Agents are usually largely dependent on one project for their income. Uncertainty can therefore result in large fluctuations in the salary of the agent, which is usually not appre-

ciated. *Risk aversion* is the term used for this attitude towards risk. The specification of the payment function of the agent exhibits risk aversion. A salary with certainty is valued higher than an uncertain salary which is on average the same. (Mathematically, $\alpha\sqrt{w_1} + (1-\alpha)\sqrt{w_2} < \sqrt{(\alpha w_1 + (1-\alpha)w_2)}$, where w_1 and w_2 are two different salary levels and is a number between 0 and 1. The concavity of the payment function of the agent is responsible for this inequality.) Appendix 6.1 provides a graphical presentation of risk aversion.

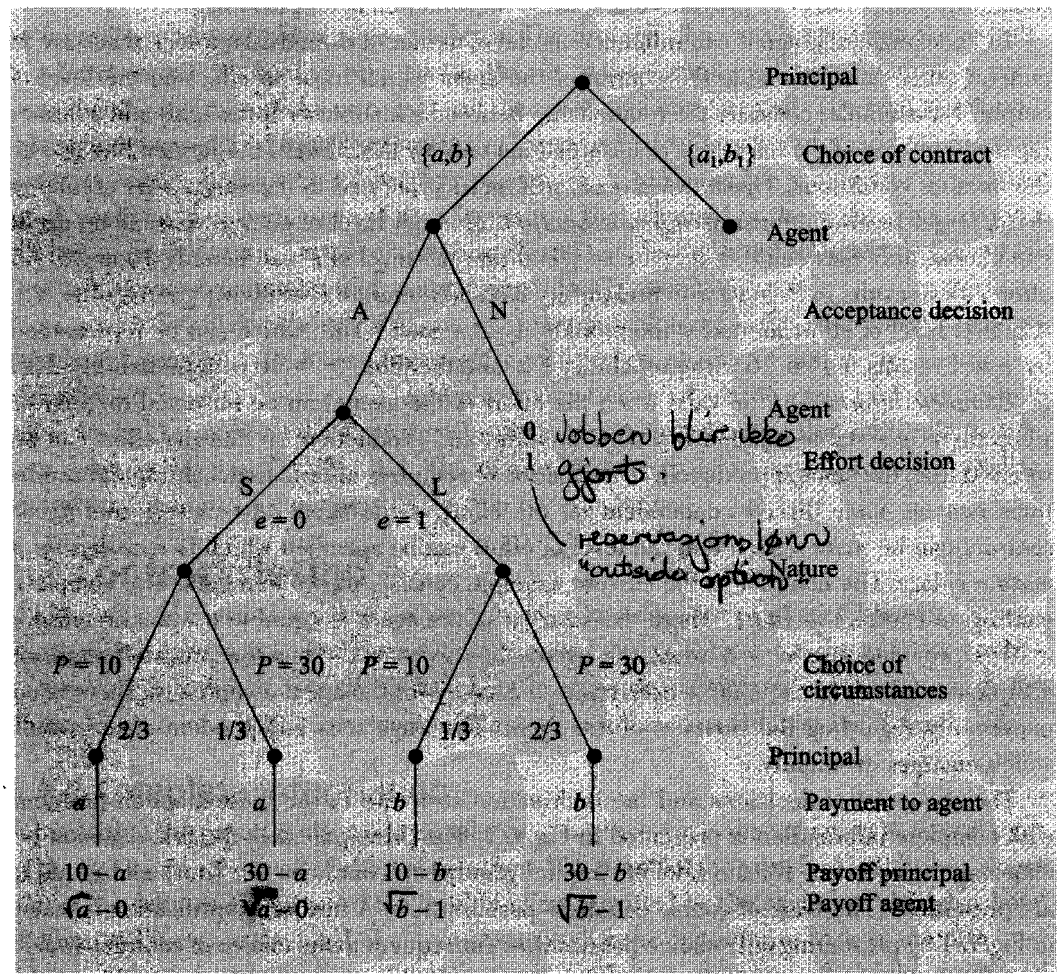
In choosing e, the agent can influence the level of output directly. However, there are in general other factors outside the control of the agent which have an effect on the level of output. For example, consider the relationship between a landowner (principal) and a farmer (agent). The size of the harvest is determined not only by the effort of the farmer, but also by the weather conditions. These two aspects will be incorporated in the analysis by assuming that a larger level of effort raises the *probability* of a high level of output. Assume an agent can choose only between $e = 0$ and $e = 1$ and that the level of P can be only 10 or 30. An effort $e = 0$ results in $P = 10$ with probability 2/3 and therefore $P = 30$ with probability 1/3. A higher level of effort increases the probability of a good result, which can be represented by '$e = 1$ results in $P = 10$ with probability 1/3' and therefore '$P = 30$ with probability 2/3'.

Complete information prevails when the effort of the agent can be observed directly or when there is a stable relationship between effort and production, so that the effort can be inferred from the amount produced. In a situation of complete information, contractual conditions can be made directly dependent on the effort of the agent. A *complete contingent contract* can be written such that the level of effort can be specified which is required for a certain salary. The contract in the current example consists of two numbers. The complete contingent contract is $\{a,b\}$, where the salary w of the agent is equal to a when an effort $e = 0$ is provided and $w = b$ when the agent chooses $e = 1$. Therefore, in a situation of complete information the effort e determines the salary for the agent completely. There is no uncertainty regarding the salary w of the agent. The wage w is independent of the result which emerges eventually.

The sequence of decisions and the information structure in the hidden action problem with complete information is presented in Fig. 6.1. The principal takes the first decision by choosing the contract. For the sake of simplicity, only two contracts, i.e. $\{a,b\}$ and $\{a_1,b_1\}$, are presented. (There are of course countless possibilities.) A further simplification is made in Fig. 6.1 by presenting only choice possibilities subsequent to the choice of contract $\{a,b\}$. (All other contracts should have the same sequence of subsequent decisions, but this would unnecessarily clutter the figure.) After the choice of contract by the principal, the agent has to decide regarding acceptance. If the agent does not accept (N), then no further decisions are made. The principal does not earn anything, while the agent goes for his or her outside opportunity and earns the reservation wage 1. If the agent accepts (A) the contract, then he or she has to take a second decision. This third decision entails the choice of effort, i.e. $e = 0$ or $e = 1$.

External circumstances as well as the choice of effort of the agent determine the level of output. This is incorporated in Fig. 6.1 as the fourth decision. The artificial player 'Nature' decides whether the result will be 10 or 30, where the level of effort of the agent determines the probability of the final result. If the agent chooses $e = 0$, Nature will choose a bad result with probability 2/3. A high level of effort will result in a bad result with a probability of only

1/3. Finally, a fifth decision moment is incorporated to facilitate the comparison with the situation of asymmetric information. This means that the principal pays the agent according to the contract. There is only one choice possible, because the contract specifies for each possible situation exactly how much the principal has to pay the agent.



w = a hvis e = 0
w = b hvis e = 1.

Figure 6.1: Decision order and complete information

The choice of acceptance of the contract and the choice of the level of effort by the agent have to be taken into account in the design of a meaningful contract. Backward induction (Sec. 2.2.4) dictates that we start with the final decision of the agent. The agent chooses an effort level $e = 1$ instead of $e = 0$ when this yields more than making no effort. The payoff of the agent in the right block in Fig. 6.2 has therefore to be higher than in the left block in order to have him or her put forward a high level of effort, i.e. $\sqrt{b} - 1 \geq \sqrt{a} - 0$. This is called the *incentive compatibility constraint.*

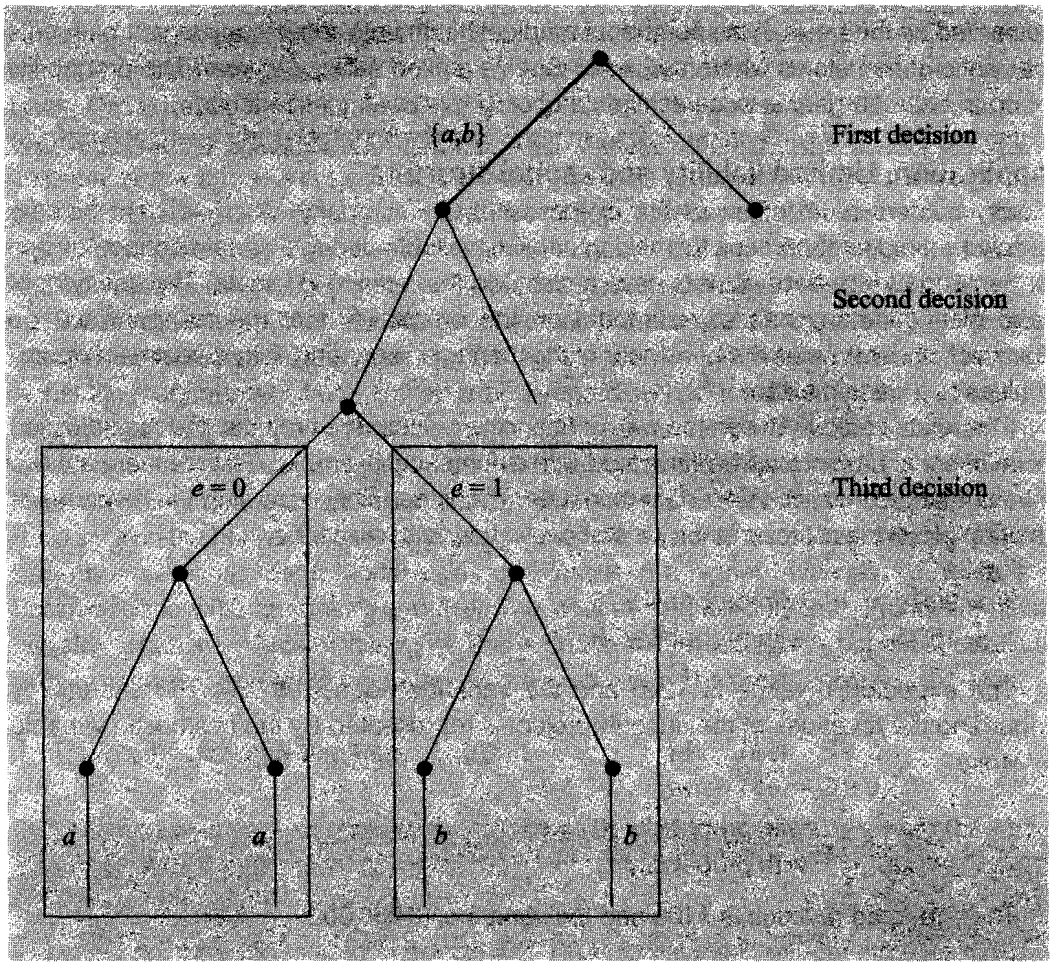


Figure 6.2: Incentive compatibility constraint when there is complete information

Application: Tonsil and open heart surgeries

In a number of countries, a continuing subject of public debate is the organization of the health service. Hot issues are the introduction of new technologies, the influence of the system of legal responsibility for mistakes in the number of tests performed, the extent of medical care in the terminal life phase and the payment system for medical employees. Califano (1986) has collected some remarkable facts regarding the impact of rules and institutions on the costs of the US health service. The focus is here on the impact of the payment system for medical specialists on the number of treatments.

The United States of America is especially suitable for conducting comparative studies in the medical sector, because each state has its own medical policy. It turns out that large geographical variations exist regarding the number of medical treatments. The role of the reward system is remarkable. States where medical specialists (agents) are

A final remark regarding limited liability and investment selection concerns the frequently used criterion of *net present value* for choosing investment projects. The net present value is determined by discounting the expected future cash flows, in which the costs of capital and the risk associated with a project are taken into account. The above numerical example shows that other considerations, which do not necessarily match the interests of the company, play a role in the choice of investment projects. It is therefore to be expected that companies will defend themselves by gathering extensive information about potential projects as well as the person(s) executing them. In practice, various rules and procedures have to be followed in order to get a project accepted.

The principal has, in addition to the incentive compatibility constraint, also to take into account that the agent has opportunities elsewhere. A contract will be accepted by the agent only when he or she earns at least as much with the contract as without it. This second constraint in the design of a meaningful contract is called the *participation constraint*. The payoff of the agent with the contract depends on the level of effort which is put forward, i.e. the incentive compatibility constraint has to be incorporated in the specification of the participation constraint. The agent will choose $e = 1$ once the contract has been accepted when the incentive compatibility constraint is met, i.e. the agent earns $\sqrt{b} - 1$. Contract $\{a,b\}$ will be accepted when $\sqrt{b} - 1 \geq 1$. This inequality is called the participation constraint. The participation constraint requires that the payment for the agent in the left block of Fig. 6.4 should be at least as high as in the right block.

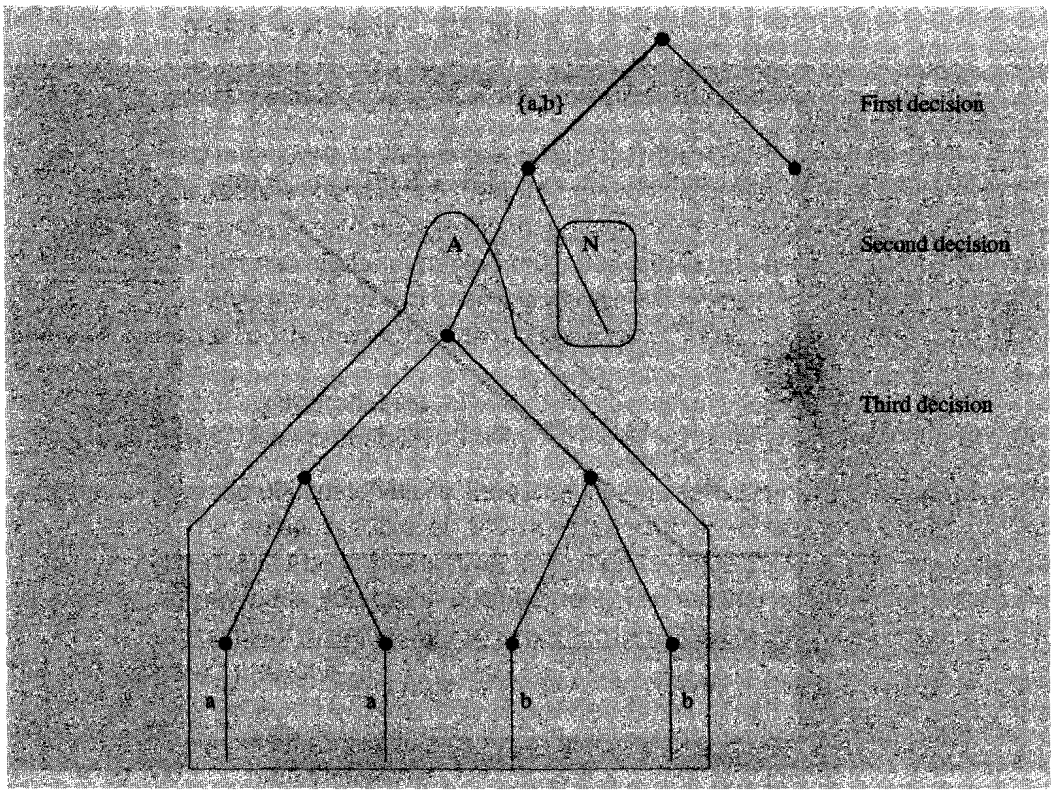


Figure 6.4: Participation constraint when there is complete information

Application: Subcontracting in Japan

One of the characteristics of Japanese industry is the tight relationship between firms and their *suppliers*. Inputs are more often procured from third parties in Japan than in the United States: 69 per cent of the value of output is obtained by a contract with suppliers in Japan, whereas this is 58 per cent in the United States (Kawasaki and McMillan, 1987). Viewed from the perspective of Berle and Means (1932), this is an attractive situation for Japanese companies. There will be less 'corporate plundering' because there is no separation of ownership and control with external procurement through independent suppliers.

It is sometimes suggested that subcontractors are in an undesirable position and can hardly survive. This is reflected in the sequence of decisions in the principal–agent problem. The large company has a strong bargaining position because it formulates the procurement proposal. However, the subcontractor is not powerless. First, he or she can refuse the contract when a more attractive alternative is available. It is important to have alternative sources of demand. Subcontractors are aware of their bad position relative to one large customer. Even the smallest Japanese subcontractors have on average three large companies as customers for their products, and this number increases with the growth of the subcontractor. This is illustrated in Table 6.5 (Kawasaki and McMillan, 1987). Second, the subcontractor still has to choose an action which is important for the success of the project. The subcontractor has superior information regarding local circumstances, which can be used to his or her advantage in the bargaining about the price.

Size of subcontractor	Average number of customers
1–3 employees	3
20–29 employees	6
200–299 employees	11

Figure 6.5: Bargaining position of Japanese subcontractors

The contract $\{a,b\}$ will be accepted by the agent and will result in an effort $e = 1$ when the incentive constraint $\sqrt{b} - 1 \geq \sqrt{a} - 0$ as well as the participation constraint $\sqrt{b} - 1 \geq 1$ are both met. There are many values of a and b which meet both of these constraints, which is illustrated by the shaded area in Fig. 6.6. The principal chooses the contract which maximizes his or her profit. This is the case when $a = 0$ and $b = 4$. The contract $\{0,4\}$ means that the agent receives nothing when $e = 0$ is provided and is paid a wage 4 when an effort $e = 1$ is put forward. The contract $\{0,4\}$ yields the agent $\sqrt{4} - 1 = 1$ and the principal earns $1/3 \times 10 + 2/3 \times 30 - 4 = 58/3$.

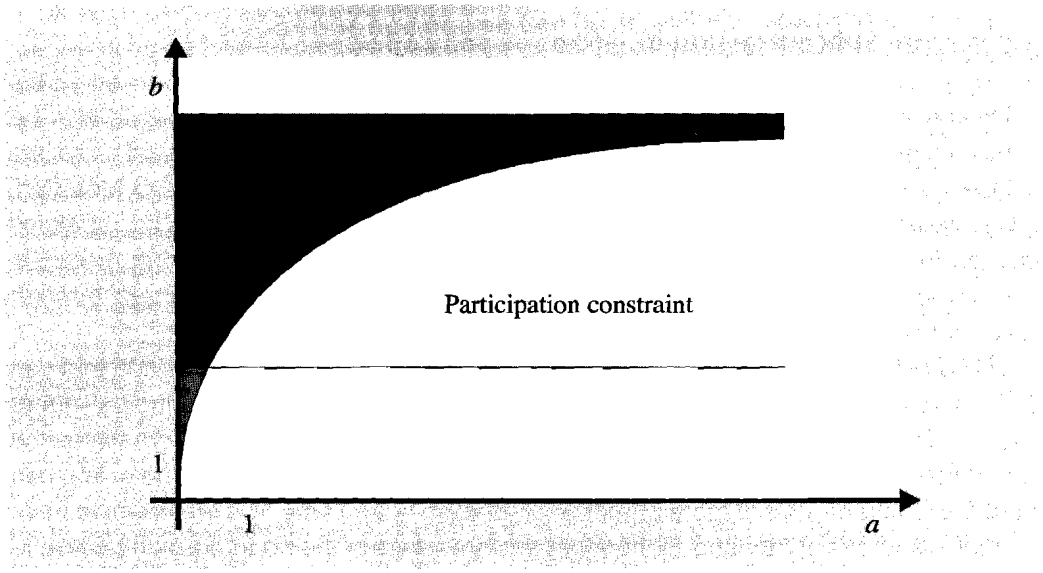


Figure 6.6: Incentive and participation constraints when there is complete information

Notice that the result is still uncertain, but the risk-neutral principal bears all the risk. The agent receives a wage of 4 when $e = 1$ is chosen, while the principal receives the (uncertain) output. The allocation of risk is Pareto-optimal, because the risk-neutral principal is better able to bear the risk than the risk-averse agent.

6.1.2 Incomplete information

Assume that only the agent knows the choice of e and the specific circumstances. The principal observes only the final result. This situation is characterized as a situation with asymmetric information. Figure 6.7 represents the change in the information structure. One information set applies to the situation where the principal observes result $P = 10$, while the other information set is geared towards the observation $P = 30$. A result $P = 10$ is composed of two effects: a choice of effort by the agent and the decision of Nature regarding the circumstances. The principal is not able to distinguish these two effects. Only the result $P = 10$ is observed, not the level of effort. The same applies to $P = 30$.

A meaningful contract can be based only on *observable facts*, and is therefore simple to achieve in a situation of complete information, because all relevant information is available and payments can thus be made fully dependent or contingent on the effort e of the agent. However, it is not possible in a situation with incomplete or asymmetric information. Only the result R is observable to the principal, not the level of effort e. The wage of the agent can therefore be made dependent only on the level of output. Complete contingent contracts are not possible anymore in a situation with asymmetric information. There can only be *complete contracts*.

A complete contract $[y,z]$ consists also of two numbers. However, the interpretation of these numbers is quite different from that in the example above. The two numbers of the complete contingent contract $\{a,b\}$ are geared towards effort levels, whereas the two

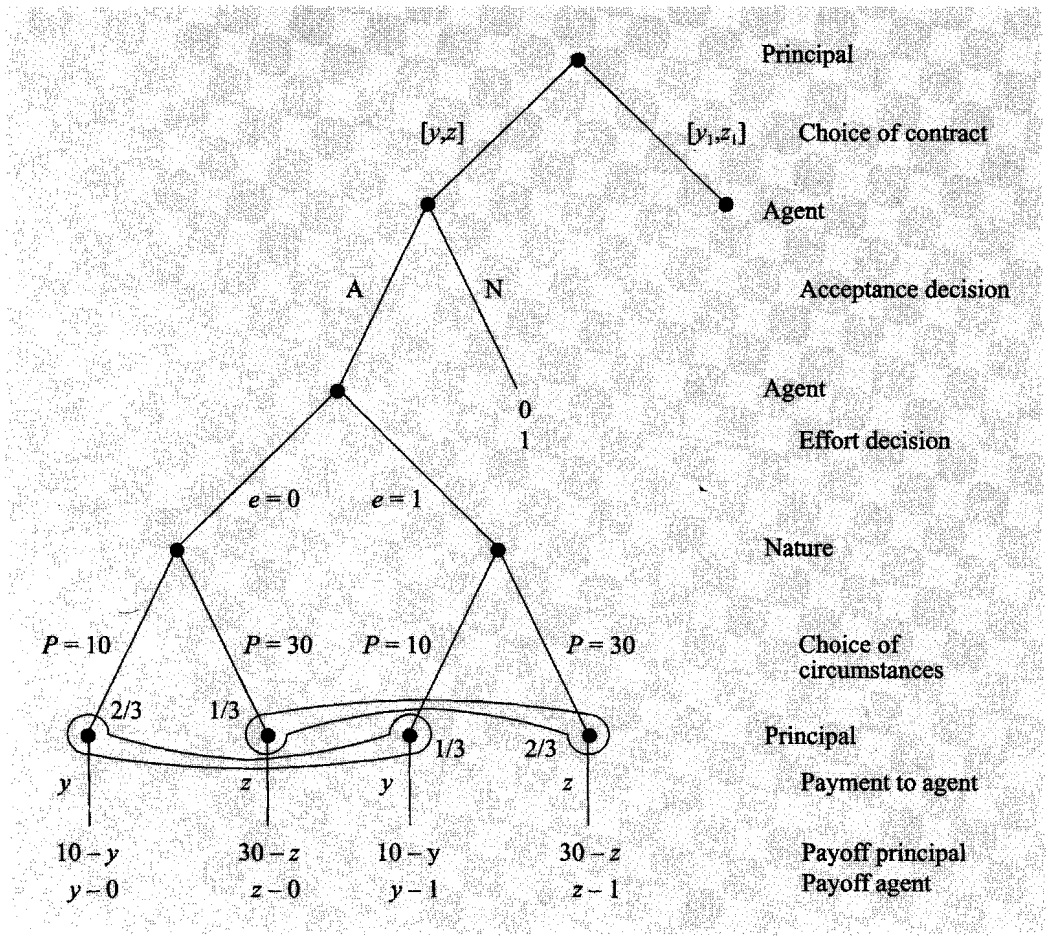


Figure 6.7: Decision order and asymmetric information

numbers of the complete contract $[y,z]$ are geared towards the two levels of output. The agent receives $w = y$ when $P = 10$ and $w = z$ when $P = 30$. (Note that the complete contract is presented with square brackets in order to distinguish it from the complete contingent contract $\{a,b\}$.)

Again the payoff-maximizing contract of the principal will be determined, while taking the considerations of the agent into account. The agent chooses effort $e = 1$ when this is more attractive than the choice $e = 0$. Figure 6.8 illustrates this incentive compatibility constraint. It entails that the agent earns more with $e = 1$ than with $e = 0$, i.e. the expected payoff of the agent in the left block has to be lower than the expected payoff in the right block. *Expected* payments have to be compared because there is now some uncertainty regarding the wage of the agent when a choice of effort is made. An effort $e = 0$ may result in $P = 10$ or $P = 30$, each with a certain probability and an associated wage. The agent will choose $e = 1$ instead of $e = 0$ when:

$$1/3(\sqrt{y}-1)+2/3(\sqrt{z}-1) \geq 2/3(\sqrt{y}-0)+1/3(\sqrt{z}-0)$$
$$\Leftrightarrow \sqrt{z} \geq \sqrt{y}+3.$$

This inequality is called the *incentive compatibility constraint*.

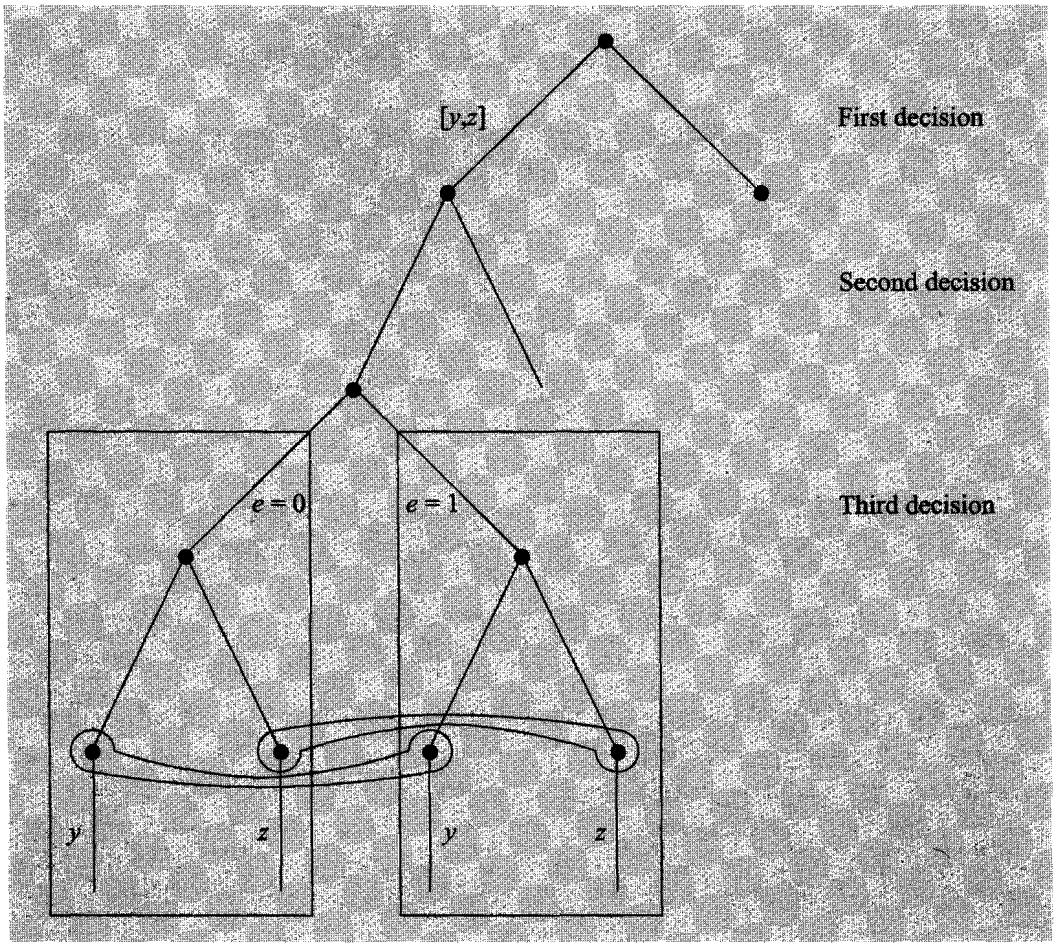


Figure 6.8: Incentive compatibility constraint under asymmetric information

A meaningful contract satisfies also the *participation constraint*. This constraint entails that the agent earns at least as much with the contract as without it, i.e. the reservation wage. Figure 6.9 illustrates this constraint. The payment in the left block has to be at least as large as the payment in the right block in order to get acceptance of the contract by the agent:

$$1/3(\sqrt{y}-1)+2/3(\sqrt{z}-1) \geq 1$$
$$\Leftrightarrow \sqrt{z} \geq -5\sqrt{y}+3.$$

The principal chooses y and z such that his or her expected payoff is maximized, while taking the incentive compatibility and the participation constraints into account. The cross-hatched area in Fig. 6.10 consists of all values of y and z satisfying these constraints. The payoff of the principal is maximized when $y = 0$ and $z = 9$. The contract [0,9] is accepted by the agent and results in an effort 1. Notice that the optimal value of y does not equal the optimal value of z. The principal appreciates a high level of effort, but the agent does not. The agent is motivated to provide a high level of effort, which increases the probability of a good result, by paying him or her more for a good result than for a bad result.

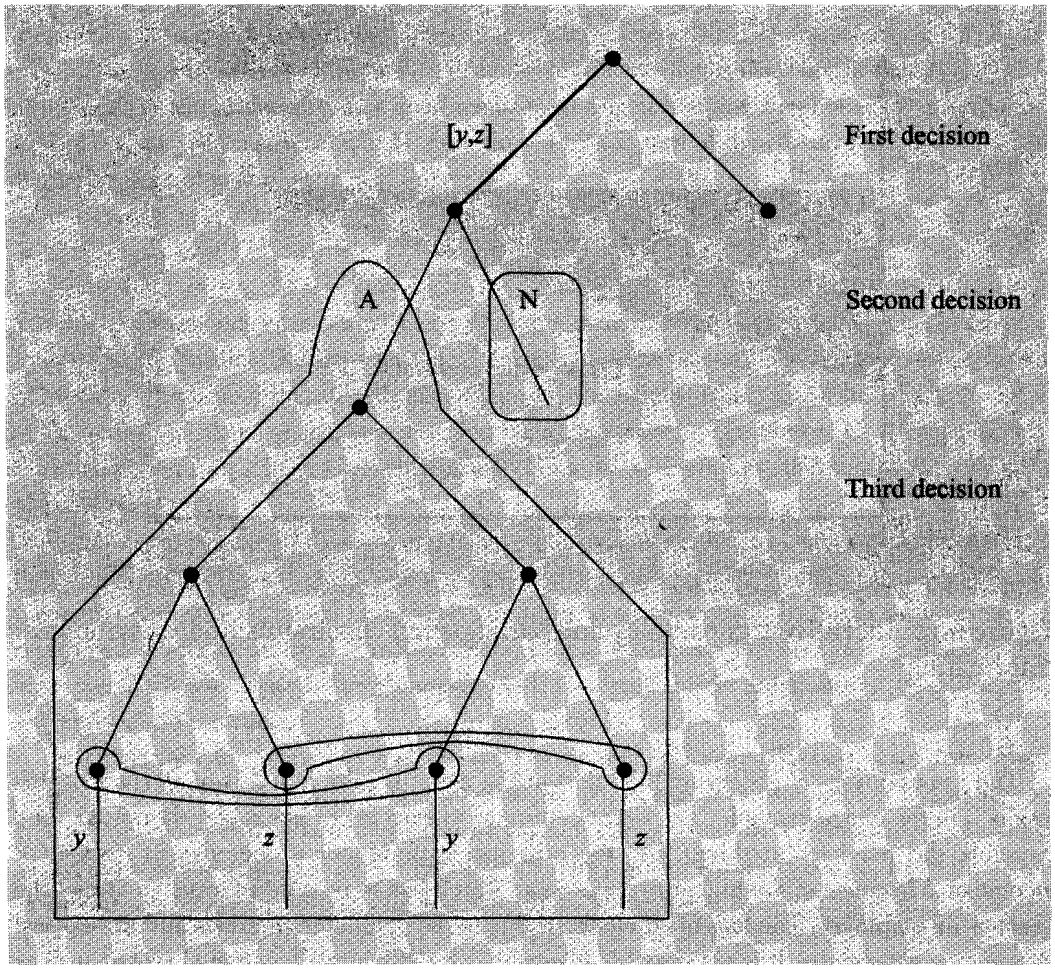


Figure 6.9: Participation constraint under asymmetric information

The agent earns again exactly $1/3(\sqrt{y} - 1) + 2/3(\sqrt{z} - 1) = 1/3(\sqrt{0} - 1) + 2/3(\sqrt{9} - 1) = 1$, i.e. his or her opportunity cost. The strong, take-it-or-leave-it *bargaining position* of the principal is responsible for this division of the surplus. The principal designs the contract, i.e. chooses y and z, in such a way which the agent just accepts the contract. However, the payment of the principal has decreased from 58/3 in the situation of complete information, to 52/3 ($= 1/3(10 - y) + 2/3(30 - z) = 10/3 + 42/3$) in the current situation of asymmetric information.

Uncertainty and risk aversion by the agent is responsible for this decrease of 2. A risk premium of 2 is paid to the agent, i.e. the expected wage paid to the agent has increased from 4 in the situation of complete information to 6 ($= y/3 + 2z/3 = 0/3 + 18/3$) in the situation of asymmetric information. The situation of incomplete information therefore implies that the agent receives part of the surplus (*informational rent*), which is due to the superior information that is at the disposal of the agent. This higher average wage is necessary because the risk-averse agent has to be compensated for bearing the risk. The agent values the uncertain average wage of 6 as high as a wage of 4 with certainty.

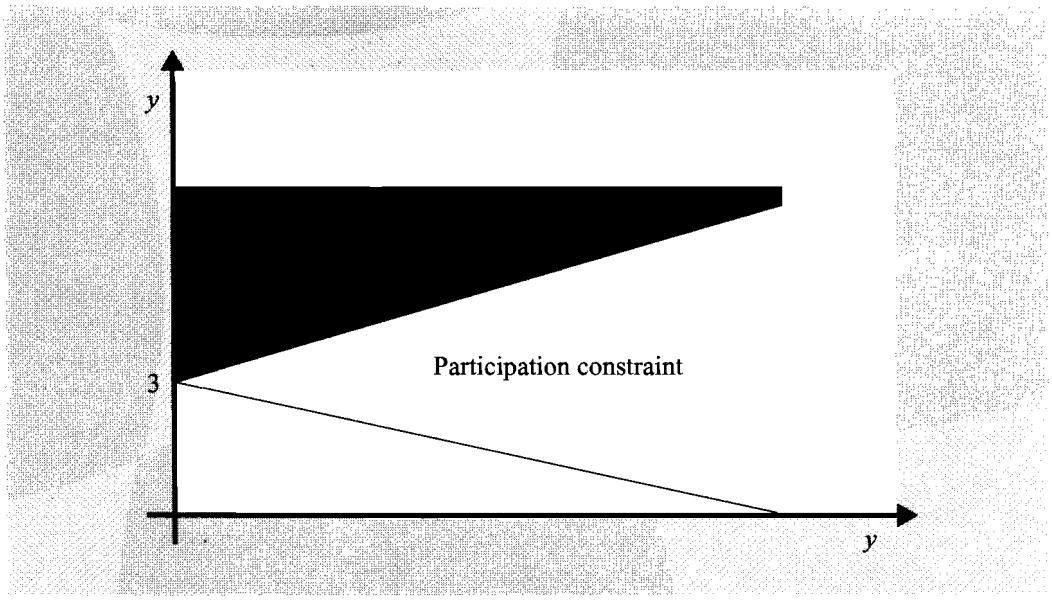


Figure 6.10: Incentive compatibility and participation constraints under asymmetric information

The impossibility of observing the effort of the agent results in a *loss of efficiency*. This loss is 2 in the above example. The agent continues to earn his or her reservation wage (and therefore did not lose anything), but the principal experiences a decrease in (expected) income of 2 because of the higher average wage which has to be paid in order to attract the agent as an employee. The loss of efficiency is due to the conflict of interests and the ex-post information asymmetry. It is not possible to establish an efficient allocation of risk as well as efficient incentives. A compromise in the design of the contract is chosen by the principal between the efficient allocation of risk and efficient performance stimuli. In the situation of complete information, the contract can be made dependent on the effort e. Strong incentives are formulated and the agent does not bear any risk. All uncertainty is ascribed to the principal, which is efficient because the principal is risk-neutral. This is not possible any more in a situation of asymmetric information, because the contract can be based only on observable variables. The optimal contract in the situation of incomplete information is a compromise between risk-spreading and performance stimuli. However, such a compromise always entails a loss of surplus.

6.2 The incentive intensity principle

This section will elaborate on the hidden action problem of the previous section. Aspects like risk-aversion, uncertainty about the environment, discretion of the agent and the impact of the agent's activities on the profit of the project will be explicitly incorporated in the analysis. The presentation of the hidden action problem will be somewhat different than in the previous section, but the underlying ideas remain the same. The first difference is that the effort of the agent will now be treated as a *continuous* variable, whereas only two levels of

effort of the agent. The optimal contract will in general be *second-best*, which indicates the importance of the principal–agent approach for the theory of the firm. The costs of asymmetric information are dealt with by other decision rules, another allocation of tasks and a contractual approach towards organizations. The principal–agent approach does not provide an exhaustive explanation of the structure and functioning of complex organizations. The model is valuable however, because it indicates the causes of and solutions for possible frictions in organizations.

Many extensions of the model discussed in this chapter are possible. First, attention was focused on two parties, namely one principal and one agent. However, organizations often consist of *many layers*, where the same person is a principal in relation to subordinates but at the same time an agent vis-à-vis a superior. This causes new problems, like forming coalitions and delegating tasks (Tirole, 1986). Second, in situations with *two-sided asymmetric information*, the principal owns valuable information too (Maskin and Tirole, 1992). Third, a source of information which has not entered in the design of contracts is the observation of the real circumstances *by the agent*. Making the payments dependent on this observation in the contract is usually attractive for the principal (Demski and Sappington, 1984). Fourth, sometimes it is possible to base the contract only on an imperfect indicator of the objective function of the principal (Baker, 1992). Fifth, situations may arise in which the principal is sensitive to *bribes*; these have not been discussed, either.

6.7 Exercises

6.1 A Which two behavioural assumptions are made in a principal–agent model?

B Which two aspects does the principal have to take into account in the design of the optimal contract in a hidden action problem?

C Why is the surplus which the principal receives in the hidden action problem in the situation with incomplete information smaller in general than in the situation with complete information?

6.2 The manager of the soccer team The Flying Boys (TFB) has decided to introduce financial incentives in the contracts of its players. A premium will be paid to the players who score. An attempt to score only succeeds with a certain probability, because the player can miss or because the ball can be stopped.

A Illustrate in a diagram the financial side of an attempt to score. This diagram has to show the two possible levels of income, the expected income from an attempt to score, the expected utility, the certain equivalent income of the player and the risk premium of a risk-averse player.

Assume that a bonus of 400 euros is paid for each goal and that the utility function of the extra income equals $U(b) = \sqrt{b}$, where b is the level of the bonus. In the last minute of the game, a TFB player is tackled and is awarded a penalty. The score is still 0–0, which makes the penalty conclusive for a tie or a win by TFB. The manager of the opponents, Polder Prinsen (PP), deviously sends one of his players to the one who is going to take the penalty in order to bribe him.

B What is the minimum payoff which has to be paid to persuade the TFB player to miss? Assume that the players are only moved by financial incentives and that the TFB player scores with a probability of .7 when he or she is not bribed.

At some point during the game Diego de Vries and Jan Romario are free in front of the PP goalkeeper. Diego is in possession of the ball and scores with a probability of .1, while Jan succeeds with a probability of .2. In the current financial system Diego prefers to shoot rather than pass to Jan. The TFB manager wants to avoid this problem in the future by awarding a bonus for a decisive assist.

C What should the bonus be to make Diego pass the ball to Jan in the same situation in the future?

6.3 A Explain the difference between a risk-averse and a risk-seeking agent. Illustrate your answer in words and with a figure.

B Describe the relationship between the behaviour of an agent towards risk and the relationship between the fixed and the variable parts in the salary of an agent for a fixed certainty equivalent income.

6.4 Contracts are used to reduce the divergence of interests between the principal and the agent. They can be very complicated, but assume there are linear contracts, i.e. a contract specifies a fixed component and a variable component based on output.

A Why is the contract based on output?

B In what way does an increase of uncertainty in the environment influence the variable part of the reward structure? Explain your answer.

C Does the profit of the principal increase when a less risk-averse agent is appointed? Explain your answer.

D In what situation is it not recommendable for the principal to use a linear contract for the activities of the agent?

6.5 Assume company A belongs to an industry in which there are many risky opportunities, while company B is in a business in which this is not possible.

A Which company will have the highest equity/debt ratio according to Jensen and Meckling? Explain your answer.

B Do Jensen and Meckling predict that the equity of restaurants will be owned largely by external stockholders?

6.6 Assume a principal has to design an optimal contract $\{m,n\}$. The payments m and n are made to the agent when the observable variable is respectively low and high. The choice of contract by the principal intends to induce the agent to provide a high level of effort. The costs of effort for the agent are 0 (1) when the level of effort is low (high). The agent is allowed to reject the contract of the principal when it is offered. This results in a payoff of 0 for the principal and 1 for the agent.

The effort of the agent together with the external circumstances determine the result R. The outcome is either $R = 5$ or $R = 40$. The effort of the agent influences the

probability of favourable circumstances. If the agent does not provide effort, then the probability of a low outcome is 3/4. If the agent does work hard, then the probability of a low level of output is 1/4.

The payment for the principal is equal to R minus the payment to the agent according tot the contract. The payments are valued by the agent as $\sqrt{m}$ and $\sqrt{n}$. The costs of effort are equal to the level of effort and have to be subtracted from this amount.

A Draw the extensive form, while assuming that the principal is not informed about the effort of the agent.

B Which two conditions does the contract $\{m,n\}$ have to satisfy in order to generate a high level of effort? Explain these conditions in words.

C Formulate these two conditions in terms of the expected payments of the agent.

6.7 Suppose there are two players, a principal and an agent. First, the principal designs a contract based on the available information. In the second period the agent decides to accept the contract or not. If the agent does not accept the contract, the relationship ends and each player receives a payment 0. Finally, the agent chooses to provide a low (L) or a high (H) level of effort during the execution of the assignment.

R=0.

Assume that there is a situation of complete information, which means that the principal can observe the level of effort of the agent. Therefore the principal is able to offer a contract $\{w(L), w(H)\}$, where $w(L)$ is the payment for the agent when effort L is provided and $w(H)$ is the payment for the agent when effort H is put forward. The payment of the principal is $9 - w(L)$ and $w(L) - 1$ for the agent when an effort L is provided. If the level of effort is H, then the principal receives $16 - w(H)$ and the agent $w(H) - 2$.

A Draw the extensive form.

B Which inequality has to hold such that the agent provides a level of effort H once the agent has accepted the contract?

C Which inequality has to be satisfied for the agent to be willing to accept the contract, given that an effort H will be put forward in the final period?

D Determine the payoff-maximizing contract.

Assume the principal can observe only the output of the agent, i.e. 9 or 16, but not any more the level of effort L or H. The probability of output level 9 and 16 is influenced by the effort of the agent. The probability of output 9 (16) is .6 (.4) when an effort level L is provided, while an effort H results in 9 (16) with a probability .4 (.6).

E Draw the extensive form.

F What does a contract in this situation with incomplete information look like?

G Which inequality has to hold for the agent to provide a level of effort H once the agent has accepted the contract?

H Which inequality has to be satisfied for the agent to accept the contract, given that an effort H will be put forward in the final period?

I Determine the payoff-maximizing contract.

6.8 A State and explain the incentive-intensity principle.

Assume that the expected output is a function of the effort of the agent $P(e) = 60 + 40e$. A specific level of output is subject to various uncertain factors, which are summa-