10 Asymmetric Information

10.1 Introduction

A key feature of the real world is asymmetric information. Most people want to find the right partner, one who is caring, kind, healthy, intelligent, attractive, trustworthy, and so on. While attractiveness may be easily verified at a glance, many other traits people seek in a partner are difficult to observe, and people usually rely on behavioral signals that convey partial information. There may be good reasons to avoid a potential mate who is too eager to start a relationship with you, as this may suggest unfavorable traits. Similarly it is hard not to infer that people who participate in dating services must be on average less worth meeting, and the consensus appears to be that these services are a bad investment. The reason is that the decision to resort to a dating agency identifies people who have trouble initiating their own relationships, which is indicative of other unwelcome traits. The lack of information causes caution in dating, which can result in good matches being missed.

Asymmetric information arises in economics when the two sides of the market have different information about the goods and services being traded. In particular, sellers typically know more about what they are selling than buyers do. This can lead to adverse selection where bad-quality goods drive out good-quality goods, at least if other actions are not taken. Adverse selection is the process by which buyers or sellers with "unfavorable" traits are more likely to participate in the exchange. Adverse selection is important in economics because it often eliminates exchange possibilities that would be beneficial to both consumers and sellers alike. There might seem some easy way to resolve the problem of information asymmetry: let everyone reveal what they know. Unfortunately, individuals do not necessarily have the incentive to tell the truth (think about the mating example or the market identification of high- and low-ability people).

Information imperfections are pervasive in the economy, and in some sense, it is an essential feature of a market economy that different people know different things. While such information asymmetries inevitably arise, the extent to which they do so and their consequences depends on how the market is organized. The anticipation that they will arise also affects market behavior. In this chapter we discuss the ways in which information asymmetries affect market functioning and how they can be partially overcome through policy intervention. We do not consider how the agents can *create* information problems, for example, in an attempt to exploit market power by differentiating products or by taking actions to increase information asymmetries as in the general governance problem.

One fundamental lesson of information imperfection is that *actions convey information*. This is a commonplace observation in life, but it took some time for economists to fully appreciate its profound effects on how markets function. Many examples can be given. A willingness to purchase insurance at a given price conveys information to an insurance company, because those most likely to decide that the insurance is not worthwhile are those who are least likely to have an accident. The quality of a guarantee offered by a firm conveys information about the quality of its products as only firms with reliable products are willing to offer a good guarantee. The number of years of schooling may also convey information about the ability of an individual. More able people may go to school longer and the higher wage associated with more schooling may simply reflect the sorting that occurs rather than the ability-augmenting effect of schooling itself. The willingness of an investor to self-finance a large fraction of the cost of a project conveys information about his belief in the project. The size of deductibles and co-payments that an individual chooses in an insurance contract may convey information that he is less risk prone. The process by which individuals reveal information about themselves through the choices that they make is called *self-selection*.

Upon recognizing that actions convey information, two important results follow. First, when making decisions, agents will not only think about what they prefer, but they will also think about how their choice will affect others' beliefs about them. So I may choose longer schooling not because I value what is being taught, but because it changes others' beliefs concerning my ability. Second, it may be possible to design a set of choices that would induce those with different characteristics to effectively reveal their characteristics through their choices. As long as some actions are more costly for some types than others, it is an easy matter to construct choices that separate individuals into classes: self-selection mechanisms could, and would, be employed to screen. For example, insurance companies may offer a menu of transaction terms that will separate out different classes of risk into preferring different parts of the menu.

In equilibrium both sides of the market are aware of the informational consequences of their actions. In the case where the insurance company or employer takes the initiative, self-selection is the main *screening* device. In the case where the insured, or the employee, takes the initiative to identify himself as a better type, it is usually considered as a *signaling* device. So the difference between screening and signaling lies in whether the informed or uninformed side of the market moves first.

Whatever the actions taken, the theory predicts that the types of transactions that will arise in practice are different from those that would emerge in a perfect-information context. The fact that actions convey information affects equilibrium outcomes in a profound way. On the one hand, since quality increases with price in adverse selection models, it may be profitable to pay a price in excess of the market-clearing price. In credit markets, the supply of loans may be rationed. In the labor market, the wage rate may be higher than the market-clearing wage, leading to unemployment. There may exist multiple equilibria. Two forms of equilibria are possible: *pooling* equilibria, in which the market cannot distinguish among the types, and *separating* equilibria, in which the different types separate out by taking different actions. On the other hand, under plausible conditions, equilibrium might not exist (in particular, if the cost of separation is too great).

Another set of issues arise when actions are not easily observable. An employer would like to know how hard his employee is working; a lender would like to know the actions the borrower will undertake that might affect the chance of reimbursement. These asymmetries of information about *actions* are as important as the situations of hidden knowledge. They lead to what is referred to as the *moral hazard problem*. This term originates from the insurance industry, which recognized early that more insurance reduces the precautions taken by the insured (and not taking appropriate precautions was viewed to be immoral, hence the name). One way to solve this problem is to try to induce desired behavior through the setting of contract terms. A borrower's risk-taking behavior may be controlled by the interest rate charged by the lender. The insured will exert more care when facing contracts with large deductibles. But, in competing for risk-averse customers, the insurance companies face an interesting trade-off. The insurance has to be complete enough so that the individual will purchase. At the same time deductibles have to be significant enough to provide adequate incentives for insured parties to take care.

This chapter will explore the consequences of asymmetric information in a number of different market situations. It will describe the inefficiencies that arise and discuss possible government intervention to correct these. Interpreted in this way, asymmetric information is one of the classic reasons for market failure and will prevent trading partners from realizing all the gains of trade. In addition to asymmetric information between trading parties, it can also arise between the government and the consumers and firms in the economy. When it does, it restricts the policies that the government can implement. Some aspects of how this affects the effectiveness of the government will be covered in this chapter; others will become apparent in later chapters. The main implication that will emerge for public intervention is that even if the government also faces informational imperfections, the incentives and constraints it faces often differ from those facing the private sector. Even when government faces exactly the same informational problems, welfare can be improved by market intervention. There are interventions in the market that can make all parties better off.

10.2 Hidden Knowledge and Hidden Action

There are two basic forms of asymmetric information that can be distinguished. *Hidden knowledge* refers to a situation where one party has more information than the other party on the quality (or "type") of a traded good or contract variable. *Hidden action* is when one party can affect the "quality" of a traded good or contract variable by some action, and this action cannot be observed by the other party.

Examples of hidden knowledge abound. Workers know more about their own abilities than the firm does; doctors know more about their own skills, the efficacy of drugs, and what treatment patients need than do either the patients themselves or the insurance companies; the person buying life insurance knows more about his health and life expectancy than the insurance firm; when an automobile insurance company insures an individual, the individual may know more than the company about her inherent driving skill and hence about her probability of having an accident; the owner of a car knows more about the quality of the car than potential buyers; the owner of a firm knows more about the firm than a potential investor; the borrower knows more about the riskiness of his project than the lender does; and not least, in the policy world, policy makers know more about their competence than the electorate.

Hidden knowledge leads to the *adverse selection* problem. To introduce this, suppose that a firm knows that there are high-productivity and low-productivity workers and that it offers a high wage with the intention of attracting high-productivity workers. Naturally this high wage will also prove attractive to low-productivity workers, so the firm will attract a combination of both types. If the wage is above the average productivity, the firm will make a loss and be forced to lower the wage. This will result in high-productivity workers leaving and average productivity falling. Consequently the wage must again be lowered. Eventually the firm will be left with only low-productivity workers. The adverse selection problem is that the high wage attracts the workers the firm wants (the high-productivity) and the ones it does not (the low-productivity). The observation that the firm will eventually be left with only low-productivity workers reflects the old maxim that "The bad drives out the good."

There are also plenty of examples of hidden action. The manager of a firm does not seek to maximize the return for shareholders but instead trades off her remuneration for less work effort. Firms may find it most profitable to make unsafe products when quality is not easily observed. Employers also want to know how hard their workers work. Insurers want to know what care their insured take to avoid an accident. Lenders want to know what risks their borrowers take. Patients want to know if doctors provide the correct treatment or if, in an attempt to protect themselves from malpractice suits, they choose conservative medicine, ordering tests and procedures that may not be in the patient's best interests, and surely not worth the costs. The tax authority wants to know if taxing more may induce people to work less or to conceal more income. Government wants to know if more generous pension replacement rates may induce people to retire earlier. A welfaristic government will worry about the recipients of welfare spending too much and investing too little, thus being more likely to be in need again in the future. This concern will also be present among altruistic parents who cannot commit not to help out their children when needy and governments who cannot commit not to bail out firms with financial difficulties.

From hidden actions arises the *moral hazard* problem. This refers to the inefficiency that arises due to the difficulties in designing incentive schemes that ensure the right actions are taken. For instance, the price charged for insurance must take into account the fact that an insured person may become more careless once they have the safety net of insurance cover.

10.3 Actions or Knowledge?

Although the definitions given above make moral hazard and adverse selection seem quite distinct, in practice, it may be quite difficult to determine which is at work. The following example, due to Milgrom and Roberts, serves to illustrate this point.

A radio story in the summer of 1990 reported a study on the makes and models of cars that were observed going through intersections in the Washington, DC, area without stopping at the stop signs. According to the story, Volvos were heavily overrepresented: the fraction of cars running stop signs that were Volvos was much greater than the fraction of Volvos in the total population of cars in the DC area. This is initially surprising because Volvo has built a reputation as an especially safe car that appeals to sensible, safety-conscious drivers. In addition Volvos are largely bought by middle-class couples with children. How then is this observation explained?

One possibility is that people driving Volvos feel particularly safe in this sturdy, heavily built, crash-tested car. Thus they are willing to take risks that they would not take in another, less safe car. This implies that driving a Volvo leads to a propensity to run stop signs. This is essentially a moral hazard explanation: the car is a form of insurance, and having the insurance alters behavior in a way that is privately rational but socially undesirable.

A second possibility is that the people who buy Volvos know that they are bad drivers who are apt, for example, to be paying more attention to their children in the back seat than to stop signs. The safety that a Volvo promises is then especially attractive to people who have this private information about their driving, so they buy this safe car in disproportionately large numbers. Hence a propensity for running stop signs leads to the purchase of a Volvo. This is essentially a self-selection story: Volvo buyers are privately informed about their driving habits and abilities and choose the car accordingly.

This self-selection is not necessarily adverse selection. It only becomes adverse selection if it imposes costs on Volvo. Quite the opposite may in fact be true, and the self-selection of customers can be very profitable.

It is also typically difficult to disentangle the moral hazard problem from the adverse selection problem in antipoverty programs because it is difficult to decide whether poverty is due to a lack of productive skill (adverse selection) or rather to a lack of effort from the poor themselves who know they will get welfare assistance anyway (moral hazard).

10.4 Market Unraveling

10.4.1 Hazard Insurance

In the Introduction we noted that asymmetric information can lead to a breakdown in trade as the less-informed party began to realize that the least desirable potential partners are those who are more willing to exchange. This possibility is now explored more formally in a model of the insurance market in which individuals differ in their accident probabilities. The basic conclusion to emerge is that in equilibrium some consumers do not purchase insurance, even though they could profitably be sold insurance if accident probabilities were observable to insurance companies.

Assume that there is a large number of insurance companies and that the insurance market is competitive. The insurance premium is based on the level of expected risk among those who accept offers of insurance. Competition ensures that profits are zero in equilibrium through entry and exit. Furthermore, if there is any new insurance contract that can be offered that will make a positive profit given the contracts already available, then one of the companies will choose to offer it.

The demand for insurance comes from a large number of individuals. These can be broken down into many different types of individual who differ in their probability of incurring damage of value $d = 1$. The probability of damage for an individual is given by θ. Different individuals have different values of θ, but all values lie between 0 and 1. If $\theta = 1$, the individual is certain to have an accident. Asymmetric information is introduced by assuming that each individual knows their own value of θ but that it is not observable by the insurance companies. The insurance companies do know (correctly) that risks are uniformly distributed in the population over the interval [0, 1].

All of the individuals are risk averse, meaning that they are willing to pay an insurance premium to avoid facing the cost of damage. For each type the maximal insurance premium that they are willing to pay, $\pi(\theta)$, is given by

$$\pi(\theta) = [1 + \alpha]\theta, \tag{10.1}$$

where $\alpha > 0$ measures the level of risk aversion.

The assumption of competition among the insurance companies implies that in equilibrium they must earn zero profits. Now assume that insurance companies just offer a single insurance policy to all customers. Given the premium (or price) of the policy, π, the policy will be purchased by all the individuals whose expected value of damage is greater than or equal to this. That is, an individual will purchase the policy if

$$\pi\ (\theta) \geq \pi. \tag{10.2}$$

If a policy is to break even with zero profit, the premium for this policy must just equal the average value of damage for those who choose to purchase the policy. Hence (10.2) can be used to write the break-even condition as

$$\pi = E(\theta : \pi(\theta) \geq \pi), \tag{10.3}$$

which is just the statement that the premium equals expected damage. Returning to (10.1), the condition that $\pi\ (\theta) \geq \pi$ is equivalent to $[1 + \alpha]\theta \geq \pi$ or $\theta \geq \frac{\pi}{1+\alpha}$. Using the fact that the θ is uniformly distributed gives

$$E(\theta : \pi(\theta) \geq \pi) = E\left(\theta : \frac{\pi}{1+\alpha} \leq \theta \leq 1\right) = \frac{1}{2}\left[\frac{\pi}{1+\alpha} + 1\right]. \tag{10.4}$$

The equilibrium premium then satisfies

$$\pi = \frac{1}{2}\left[\frac{\pi}{1+\alpha} + 1\right], \tag{10.5}$$

or

$$\pi = \frac{1+\alpha}{1+2\alpha}. \tag{10.6}$$

This equilibrium is illustrated in figure 10.1. It occurs where the curve $E(\theta : \pi(\theta) \geq \pi)$ crosses the 45^o line—this intersection is the value given in (10.6). It can be seen from the figure that insurance is only taken by those with high risks, namely all those with risk $\theta \geq \frac{1}{1+2\alpha}$. This reflects the process of market unraveling through which only a small fraction of the potential consumers are actually served in equilibrium. The level of the premium is too high for the low-risk to find it worthwhile to take out the insurance. This outcome is clearly inefficient, since the first-best outcome requires insurance for all consumers. To see this, note that the premium a consumer of type θ is willing to pay satisfies

$$\pi(\theta) = (1+\alpha)\theta > \theta \qquad \text{for all } \theta. \tag{10.7}$$

Therefore everyone is willing to pay more than the price the insurance companies need to break even if they could observe probabilities of accident.

This finding of inefficiency is a consequence of the fact that the insurance companies cannot distinguish the low-risk consumers from the high-risk. When a single premium is offered to all consumers, the high-risk consumers force the premium up, and this drives the low-risk out of the market. This is a simple example of the mechanism of

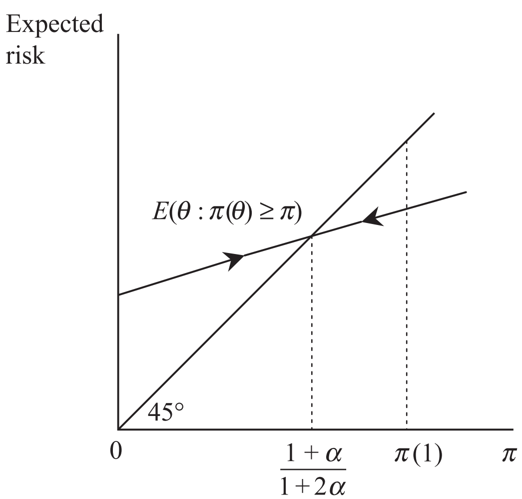

Figure 10.1
Equilibrium in the insurance market

adverse selection in which the bad types always find it profitable to enter the market at the expense of the good. Without any intervention in the market, adverse selection will always lead to an inefficient equilibrium.

10.4.2 Government Intervention

There is a simple way the government can avoid the adverse selection process by which only the worst risks purchase insurance: it is by forcing all individuals to purchase the insurance. *Compulsory insurance* is then a policy that can make many consumers better off. With this, high-risk consumers benefit from a lower premium than the actual risk they face and lower than the level in (10.6)—it will actually be $\pi = \frac{1}{2} < \frac{1+\alpha}{1+2\alpha}$. The benefit for some of the low-risk is that they can now purchase a policy at a more favorable premium than that offered if only high-risk people purchased it. This benefits those close to the average who, although paying more for the policy than the level of the actual risk they face. Only the very low-risk are made worse off—they would rather have no insurance than pay the average premium.

The imposition of compulsory insurance may seem to be a very strong policy, since in few circumstances are consumers forced by the government to make specific purchases. But it is the policy actually used for many insurance markets. For instance, both automobile insurance and employee protection insurance are compulsory. Health care insurance and unemployment insurance are also compulsory. Aircraft have to be insured. Pleasure boats have to be compulsorily insured in some countries (e.g., France) but not in others (e.g., the United Kingdom), despite their representing a much greater capital investment than automobiles. One argument that could be advanced to explain this difference is the operation of self-selection into boating as a leisure activity: those who choose to do it are by their nature either low-risk or sufficiently cautious to insure without compulsion.

There is another role for government intervention. So far the arguments have concentrated on one of the simplest cases. Particularly restrictive was the assumption that the probability of damage was uniformly distributed across the population. It was this assumption (together with the proportional reservation premium) that ensured that the curve $E(\theta : \pi(\theta) \geq \pi)$ is a straight line with a single intersection with the 45 degree line. When the uniform distribution assumption is relaxed, $E(\theta : \pi(\theta) \geq \pi)$ will have a different shape, and the nature of equilibrium may be changed. There exist in fact functions for the distribution of types that lead to multiple equilibria. Such a case is illustrated in figure 10.2. In this figure $E(\theta : \pi(\theta) \geq \pi)$ crosses the 45 degree line three times so that there are three equilibria that differ in the size of the premium. At the

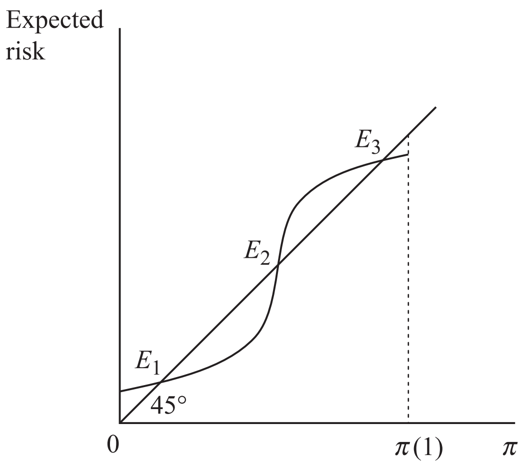

Figure 10.2
Multiple equilibria

low-premium equilibrium, E_1, most of the population is able to purchase insurance, but at the high-premium equilibrium, E_3, very few can.

Each of these equilibria is based on correct but different self-fulfilling beliefs. For example, if the insurance companies are pessimistic and expect that only high-risk consumers will take out insurance, they will set a high premium. Given a high premium, only the high-risk will choose to accept the policy. The beliefs of the insurance companies are therefore confirmed, and the economy becomes trapped in a high-premium equilibrium with very few consumers covered by insurance. This is clearly a bad outcome for the economy, since there are also equilibria with lower premiums and wider insurance coverage.

When there are multiple equilibria, the one with the lowest premium is Pareto-preferred—it gives more consumers insurance cover and at a lower price. Consequently, if one of the other equilibria is achieved, there is a potential benefit from government intervention. The policy the government should adopt is simple: it can induce the best equilibrium (that with the lowest premium) by imposing a limit on the premium that can be charged. If we are at the wrong equilibrium, the corresponding premium reduction (from $E_2 \rightarrow E_1$ or $E_3 \rightarrow E_1$) will attract the good risks, making the cheaper insurance policy E_1 sustainable. This policy is not without potential problems. To see these, assume that the government slightly miscalculates and sets the maximum premium below the premium of policy E_1. No insurance company can make a profit at this price, and all offers of insurance will be withdrawn. The policy will then worsen the outcome.

If set too high, one of the other equilibria may be established. To intervene successfully in this way requires considerable knowledge on the part of the government.

This analysis of the insurance market has shown how asymmetric information can lead to market unraveling with the bad driving out the good, and eventually to a position where fewer consumers participate in the market than is efficient. In addition asymmetric information can lead to multiple equilibria. These equilibria can also be Pareto-ranked. For each of these problems, a policy response was suggested. The policy of making insurance compulsory is straightforward to implement and requires little information on the part of the government. Its only drawback is that it cannot benefit all consumers, since the very low risk consumers are forced to purchase insurance they do not find worthwhile. In contrast, the policy of a maximum premium requires considerable information and has significant potential pitfalls.

10.5 Screening

If insurance companies are faced with consumers whose probabilities of having accidents differ, then it will be to the companies' advantage if they can find some mechanism that permits them to distinguish between the high-risk and low-risk. Doing so allows them to tailor insurance policies for each type and hence avoid the pooling of risks that causes market unraveling.

The mechanism that can be used by the insurance companies is to offer a menu of different contracts designed so that each risk type self-selects the contract designed for it. By self-select, we mean that the consumers find it in their own interest to select the contract aimed at them. As we will show, self-selection will involve the high-risks being offered full insurance coverage at a high premium, while the low-risks are offered partial coverage at a low premium requiring them to bear part of the loss. The portion they have to bear consists of a deductible (an initial amount of the loss) and co-insurance (an extra fraction of the loss beyond the deductible). An equilibrium like this where different types purchase different contracts is called a *separating* equilibrium. This should be contrasted to the *pooling* equilibrium of the previous section in which all consumers of insurance purchased the same contract. Obviously the high-risks will lose from this separation, since they will no longer benefit from the lower premium resulting from their pooling with the low-risks.

To model self-selection, we again assume that the insurance market is competitive so that in equilibrium insurance companies will earn zero profits. Rather than have a continuous range of different types, we now simplify by assuming there are just two types of agents. The high-risk agents have a probability of an accident occurring of p_h, and the low-risks a probability p_ℓ, with $p_h > p_\ell$. The two types form proportions λ_h and λ_ℓ of the total population, where $\lambda_h + \lambda_\ell = 1$. Both types have the same fixed income, r, and suffer the same fixed damage, d, in the case of an accident.

If a consumer of type i buys an insurance policy with a premium π and payout (or coverage) δ, the expected utility of this consumer type is given by

$$V_i(\delta, \pi) = p_i u(r - d + \delta - \pi) + (1 - p_i)u(r - \pi). \tag{10.8}$$

When the consumer purchases no insurance (so $\pi = 0$ and $\delta = 0$), expected utility is

$$V_i(0, 0) = p_i u(r - d) + (1 - p_i)u(r). \tag{10.9}$$

It is assumed that the consumer is risk averse, so the utility function, $u(\cdot)$, is concave.

The timing of the actions in the model is described by the following two stages:

- *Stage 1* Firms simultaneously choose a menu of insurance contracts $S_i = (\delta_i, \pi_i)$ with contract i intended for consumers of type i.
- *Stage 2* Consumers choose their most preferred contract (not necessarily the one the insurance companies intended for them!).

We now analyze the equilibrium of this insurance market under a number of different assumptions on information.

10.5.1 Perfect Information Equilibrium

In the perfect information equilibrium the insurance companies are assumed to be able to observe the type of each consumer; that is, they know exactly the accident probability of each customer. This case of perfect information is used as a benchmark to isolate the consequences of the asymmetric information that is soon to be introduced.

Figure 10.3 illustrates the equilibrium with perfect information. The curved lines are indifference curves—one curve is drawn for each type. The steeper curve is that of the high-risk. The indifference curves are positively sloped because consumers are willing to trade off greater coverage for a higher premium. They are concave because of risk aversion. It is assumed that willingness to pay for extra coverage increases with the probability of having an accident. This makes the indifference curves of the high-risk steeper at any point than those of the low-risk so that the indifference curves satisfy the *single-crossing* property. Single crossing means that any pair of indifference curves—one for the low-risk and one for the high-risk—can only cross once. With full information the insurance companies know the accident probability. They can then

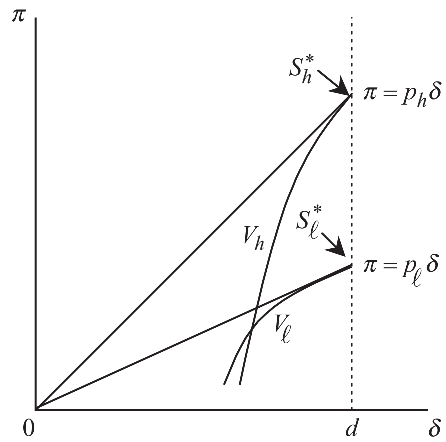

Figure 10.3
Perfect information equilibrium

offer contracts that trade off a higher premium for increased coverage at the rate of the accident probability. That is, low-risk types can be offered any contract $\{\pi, \delta\}$ satisfying $\pi = p_\ell \delta$, and the high-risk any contract satisfying $\pi = p_h \delta$. These equations give the two straight lines in figure 10.3. These are the equilibrium contracts that will be offered. To see this, note that if an insurance company offers a contract that is more generous (charges a lower premium for the same coverage), this contract must make a loss, and it will be withdrawn. Conversely, if a less generous contract is offered (so has a higher premium for the same coverage), other companies will be able to better it without making a loss. Therefore it will never be chosen.

Given this characterization of the equilibrium contracts, the final step is to observe that when these contracts are available, both types will choose to purchase full insurance coverage. They will choose $\delta = d$ and pay the corresponding premium. Hence the competitive equilibrium when types are observable by the companies is a pair of insurance contracts S_h^*, S_ℓ^*, where

$$S_h^* = (d, p_h d) \tag{10.10}$$

and

$$S_\ell^* = (d, p_\ell d), \tag{10.11}$$

so there is full coverage and actuarially fair premia are charged. As for any competitive equilibrium with full (hence symmetric) information, this outcome is Pareto-efficient.

10.5.2 Imperfect Information Equilibrium

Imperfect information is introduced by assuming that the insurance companies cannot distinguish a low-risk consumer from a high-risk. We also assume that it cannot employ any methods of investigation to elicit further information. As we will discuss later, insurance companies routinely do try to obtain further information. The reasons why they do and the consequences of doing so will become clear once it is understood what happens if they don't.

Given these assumptions, the insurance companies cannot offer the contracts that arose in the full-information competitive equilibrium. The efficient contract for the low-risk provides any given degree of coverage at a lower premium than the contract for the high-risk. Hence both types will prefer the contract intended for the low-risk (this is adverse selection again!). If offered, an insurance company will charge a premium based on the low-risk accident probability but have to pay claims at the population average probability. It will therefore make a loss and have to be withdrawn. This argument suggests what the insurance companies have to do: if they wish to offer a contract that will attract the low-risk type, the contract must be designed in such a way that it does not also attract the high-risk. This requirement places constraints on the contracts that can be offered and is what prevents the attainment of the efficient outcome.

Assume now that insurance companies offer a contract S_h designed for the high-risk and a contract S_ℓ designed for the low-risk. To formally express the comments in the previous paragraph, we say that when types are not observable, the contracts S_h and S_ℓ have to satisfy the self-selection (or incentive-compatibility) constraints. These constraints require the low-risk to find that the contract S_ℓ offers them at least as much utility as the contract S_h, with the converse holding for the high-risk. If these constraints are satisfied, the low-risk will choose the contract designed for them, as will the high-risk. The self-selection constraints can be written as

$$V_\ell(S_\ell) \geq V_\ell(S_h) \qquad (IC_u) \tag{10.12}$$

and

$$V_h(S_h) \geq V_h(S_\ell) \qquad (IC_d). \tag{10.13}$$

(These are labeled IC_u and IC_d because the first has the low-risk types looking "up" at the contract of the high-risk, the second has the high-risk looking "down" at the contract of the low-risk. This becomes clear in figure 10.4.) As we have already remarked, the contracts S_h^*, S_ℓ^* arising in the full-information equilibrium do not satisfy IC_d: the high-risk will always prefer the low-risk's contract S_ℓ^*.

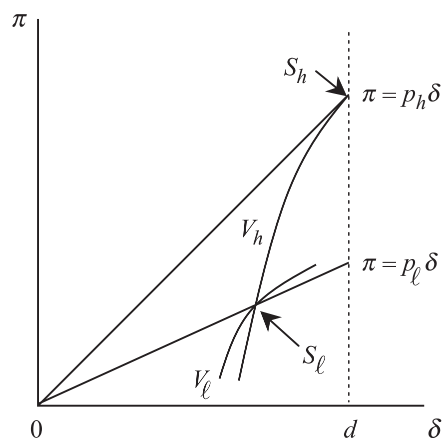

Figure 10.4
Separating contracts

There is only one undominated pair of contracts that achieves the desired separation. By undominated, we mean that no other pair of separating contracts can be introduced that makes a positive profit in competition with the undominated contracts. The properties of the pair are that the high-risk type receives full insurance at an actuarially fair rate. The low-risk do not receive full insurance. They are restricted to partial coverage, with the extent of coverage determined by where the indifference curve of the high-risk crosses the actuarially fair insurance line for the low-risk. In addition the constraint (10.13) is binding while the constraint (10.12) is not. This feature, that the "good" type (here the low-risk) are constrained by the "bad" type (here the high-risk), is common to all incentive problems of this kind.

It can easily be seen that the insurance contracts are undominated by any other pair of separating contracts and make zero profit for the insurance companies. To see that no contract can be introduced that will appeal to only one type and yield positive profit, assume that such a contract was aimed at the high-risk. Then it must be more favorable than the existing contract; otherwise, it will never be chosen. But the existing contract is actuarially fair, so any contract that is more favorable must make a loss. Alternatively, a contract aimed at the low-risk will either attract the high-risk too, and so not separate, or, if it attracts only low-risk, will be unprofitable. There remains, though, the possibility that a pooling contract can be offered that will attract both types and be profitable.

To see how this can arise, consider figure 10.5. A pooling contract will appeal to both types if it lies below the indifference curves attained by the separating contracts (lower premium and possibly greater coverage). Since the population probability of

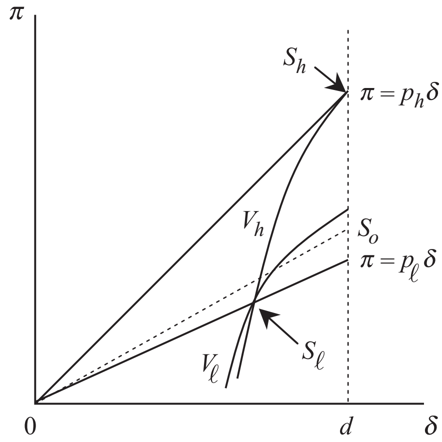

Figure 10.5
Separating and pooling contracts

an accident occurring is $p = \lambda_h p_h + \lambda_\ell p_\ell$, an actuarially fair pooling contract $\{\pi, \delta\}$ will relate premium and coverage by $\pi = p\delta$. When λ_h is large, the pooling contract will lie close to the actuarially fair contract of the high-risk and hence will be above the indifference curve attained by the low-risks in the separating equilibrium. In this case the separating contracts will form an equilibrium. Conversely, when λ_ℓ is large, the pooling contract will lie close to the actuarially fair contract for the low-risk. It will therefore be below the indifference curves of both types in the separating equilibrium and, when offered, will attract both low- and high-risk types. When this arises, the separating contracts cannot constitute an equilibrium, since an insurance company can offer a contract marginally less favorable than the actuarially fair pooling contract, attract all consumers, and make a profit.

To summarize, there exists a pair of contracts that separate the population and are not dominated by any other separating contracts. On the one hand, they constitute an equilibrium if the proportion of high-risk consumers in the population is sufficiently large (so that the low-risks prefer to separate and choose partial coverage rather than be pooled with many high-risks and pay a higher premium). On the other hand, if the proportion of low-risk is sufficiently large, there will be a pooling contract that is preferred by both types and profitable for an insurance company. In this latter case there can be no separating equilibrium.

By using the same kind of argument, it can be shown that there is no pooling equilibrium. Consider a pooling contract *S* with full coverage and average risk premium. Any

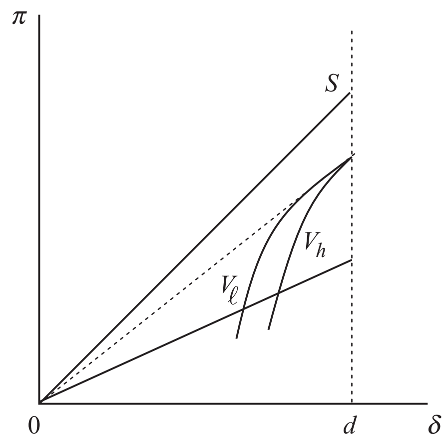

Figure 10.6
Nonexistence of pooling equilibrium

contract $S^\circ = (\delta^\circ, \pi^\circ)$ in the wedge formed by the two indifference curves in figure 10.6 attracts only low-risks and makes a positive profit. It will therefore be offered and attract the low-risk away from the pooling contract. Without the low-risk the pooling contract will make a loss.

In conclusion, there is no pooling equilibrium in this model of the insurance market. There may be a separating equilibrium, but this depends on the population proportions. When there is no separating equilibrium, there is no equilibrium at all. Asymmetric information either causes inefficiency by leading to a separating equilibrium in which the low-risk have too little insurance cover, or it results in there being no equilibrium at all. In the latter case we cannot predict what the outcome will be.

10.5.3 Government Intervention

Government intervention in this insurance market is limited by the same information restriction that affects firms: they cannot tell who is low-risk or high-risk directly but can only make inferences from observing choices. This has the consequence that it restricts policy intervention to be based on the same information as that available to the insurance companies. Even under these restrictions the government can achieve a Pareto improvement by imposing a cross-subsidy from low-risks to high-risks. It does this by subsidizing the premium of the high-risk and taxing the premium of the low-risk. It can do that without observing risk by imposing a minimal coverage for all at the average risk premium.

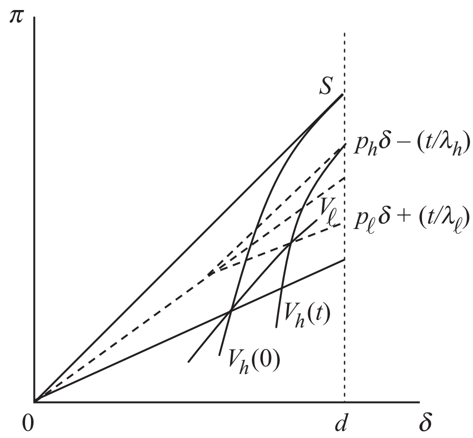

Figure 10.7
Market intervention

The reason why this policy works is that the resulting transfer from the low-risks to the high-risks relaxes the incentive constraint (IC_d). This makes the set of insurance policies that satisfies the constraints larger and so benefits both types. This equilibrium cannot be achieved by the insurance companies because it would require them all to act simultaneously. This is an example of a coordination failure that prevents the attainment of a better outcome.

This policy is illustrated in figure 10.7. Let the subsidy to the high-risk be given by t_h and the tax on the low-risk be t_ℓ. The tax and subsidy are related to the transfer, t, by the relationships $t_h = \frac{t}{\lambda_h}$ and $t_\ell = \frac{t}{\lambda_\ell}$. The premium for the low-risk then becomes $p_\ell + t_\ell$ and for the high-risks $p_h - t_h$. As figure 10.7 shows, the high-risks are strictly better off and the low-risks are as well off as before because higher coverage is now incentive compatible. The policy intervention has therefore engineered a Pareto improvement. It should be noted that the government has improved the outcome, even though it has the same information as the insurance companies. Government achieves this improvement through its ability to coordinate the transfer—something the insurance companies cannot do.

10.6 Signaling

The fundamental feature at the heart of asymmetric information is the inability to distinguish the good from the bad. This is to the detriment of both the seller of a good article, who fails to obtain its true value, and to the purchaser, who would rather pay a higher price for something that is known to be good. It seems natural that this situation would be improved if the seller could convey some information that convinces the purchaser of the quality of the product. For instance, the seller may announce the names of previous satisfied customers (employment references can be interpreted in this way) or provide an independent guarantee of quality (e.g., a report on the condition of a car by a motoring organization). Warranties can also serve as signals of quality for durable goods because, if a product is of higher quality, it is less costly for the seller to offer a longer warranty. Such information, generally termed *signals*, can be mutually beneficial.

It is worth noting the difference between screening and signaling. The less-informed players (like the insurance companies) use screening (different insurance contracts) to find out what the better-informed players (insurance customer) know (their own risk). In contrast, more-informed players use signals to help the less-informed players find out the truth.

For a signal to work it must satisfy certain criteria. First, it must be verifiable by the receiver (i.e., the less-informed agent). Being given the name of a satisfied customer is not enough—it must be possible to check back that they are actually satisfied. Second, it must be credible. In the case of an employment reference this is dependent partly on the author of the reference having a reputation to maintain and partly on the possibility of legal action if false statements are knowingly made. Finally the signal must also be costly for the sender (i.e., the better-informed agent) to obtain and the cost must differ between various qualities of sender. In the case of an employment reference this is obtained by a record of quality work. Something that is either costlessly obtainable by both the senders of low- and high-quality or equally costly cannot have any value in distinguishing between them. We now model such signals and see the effect that they have on the equilibrium outcome.

The modeling of signaling revolves around the timing of actions. The basic assumption is that the informed agent moves first and invests in acquiring a costly signal. The uninformed party then observes the signals of different agents and forms inferences about quality on the basis of these signals. An equilibrium is reached when the chosen investment in the signal is optimal for each informed agent and the inferences of the uninformed about the meaning of signals are justified by the outcomes. As we will see, the latter aspect involves self-supporting beliefs: they may be completely irrational, but the equilibrium they generate does not provide any evidence to falsify them.

10.6.1 Educational Signaling

To illustrate the consequences of signaling, we will consider a model of productivity signaling in the labor market. The model has two identical firms that compete for workers through the wages they offer. The set of workers can be divided into two types according to their productivity levels. Some of the workers are innately low-productivity in the form of employment offered by the firms, while the others are high-productivity. Without any signaling, the firms are assumed to be unable to judge the productivity of a worker.

The firms cannot directly observe a worker's type before hiring, but high-productivity workers can signal their productivity by being educated. Education itself does not alter productivity, but it is costly to acquire. Firms can observe the level of education of a potential worker and condition their wage offer on this. Hence education is a signal. Investment in education will be worthwhile if it earns a higher wage. To make it an effective signal, it must be assumed that obtaining education is more costly for the low-productivity than it is for the high-productivity; otherwise, both will have the same incentive for acquiring it.

Formally, let θ_h denote the productivity of a high-productivity worker and θ_ℓ that of a low-productivity worker, with $\theta_h > \theta_\ell$. The workers are present in the population in proportions λ_h and λ_ℓ, so $\lambda_h + \lambda_\ell = 1$. The average productivity in the population is given by

$$E(\theta) = \lambda_h \theta_h + \lambda_\ell \theta_\ell. \tag{10.14}$$

Competition between the two firms ensures that this is the wage that would be paid if there were no signaling and the firms could not distinguish between workers. For a worker of productivity level θ, the cost of obtaining education level e is

$$C(e, \theta) = \frac{e}{\theta}, \tag{10.15}$$

which satisfies the property that any given level of education is more costly for a low-productivity worker to obtain.

The firms offer wages that are (potentially) conditional on the level of education; "potentially" is added because there may be equilibria in which the firms ignore the signal. The wage schedule is denoted by $w(e)$. Given the offered wage schedule, the workers aim to maximize utility, which is defined as wages less the cost of education. Hence their decision problem is

$$\max_{\{e\}} w(e) - \frac{e}{\theta}. \tag{10.16}$$

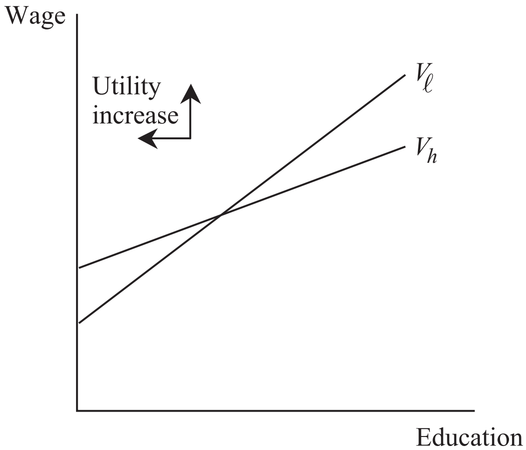

Figure 10.8
Single-crossing property

As shown in figure 10.8, the preferences in (10.16) satisfy the single-crossing property when defined over wages and education. Here V_ℓ denotes an indifference curve of a low-productivity worker and V_h that of a high-productivity type. At any point the greater marginal cost of education for the low-productivity type implies that they have a steeper indifference curve.

An equilibrium for this economy is a pair $\{e^*(\theta), w^*(e)\}$, where $e^*(\theta)$ determines the level of education as a function of productivity and $w^*(e)$ determines the wage as a function of education. In equilibrium these functions must satisfy three properties:

1. No worker wants to change his education choice given the wage schedule $w^*(e)$.
2. No firm wants to change its wage schedule given its beliefs about worker types and education choices $e^*(\theta)$.
3. Firms have correct beliefs given the education choices.

The first candidate for an equilibrium is a separating equilibrium in which low- and high-productivity workers choose different levels of education. Any separating equilibrium must satisfy

(i) $e^*(\theta_\ell) \neq e^*(\theta_h)$,
(ii) $w^*(e^*(\theta_\ell)) = \theta_\ell$,
$w^*(e^*(\theta_h)) = \theta_h$,

(iii) $w^*(e^*(\theta_\ell)) - \frac{e^*(\theta_\ell)}{\theta_\ell} \geq w^*(e^*(\theta_h)) - \frac{e^*(\theta_h)}{\theta_\ell}$,
(iv) $w^*(e^*(\theta_h)) - \frac{e^*(\theta_h)}{\theta_h} \geq w^*(e^*(\theta_\ell)) - \frac{e^*(\theta_\ell)}{\theta_h}$.

Condition (i) is the requirement that low- and high-productivity workers choose different education levels, (ii) that the wages are equal to the marginal products, and (iii) that the choices are individually rational for the consumers. The values of the wages given in (ii) are a consequence of signaling and competition between firms. Signaling implies workers of different productivities are paid different wages. If a firm paid a wage above the marginal product, it would make a loss on each worker employed. This cannot be profit maximizing. Alternatively, if one firm paid a wage below the marginal productivity, the other would have an incentive to set its wage incrementally higher. This would capture all the workers of that productivity level and would be the more profitable strategy. Therefore the only equilibrium values for wages when signaling occurs are the productivity levels. This leaves only the levels of education to be determined.

The equilibrium level of education for the low-productivity workers is found by noting that if they choose not to act like the high-productivity, then there is no point in obtaining any education—education is simply a cost that does not benefit them. Hence $e^*(\theta_\ell) = 0$. By this fact and that wages are equal to productivities, the level of education for the high-productivity workers can be found from the incentive compatibility constraints. From (iiia),

$$\theta_\ell \geq \theta_h - \frac{e^*(\theta_h)}{\theta_\ell}, \tag{10.17}$$

or

$$e^*(\theta_h) \geq \theta_\ell[\theta_h - \theta_\ell]. \tag{10.18}$$

Condition (10.18) provides the minimum level of education that will ensure that the low-productivity workers choose not to be educated. Now from (iiib) it follows that

$$\theta_h - \frac{e^*(\theta_h)}{\theta_h} \geq \theta_\ell, \tag{10.19}$$

or

$$\theta_h[\theta_h - \theta_\ell] \geq e^*(\theta_h). \tag{10.20}$$

Hence a complete description of the separating equilibrium is

$$e^*(\theta_\ell) = 0, \theta_\ell [\theta_h - \theta_\ell] \leq e^*(\theta_h) \leq \theta_h [\theta_h - \theta_\ell], \tag{10.21}$$

$$w\left(e^*(\theta_\ell)\right) = \theta_\ell, w\left(e^*(\theta_h)\right) = \theta_h, \tag{10.22}$$

so the low-productivity workers obtain no education, the high-productivity have education somewhere between the two limits and both are paid their marginal products. An equilibrium satisfying these conditions is illustrated in figure 10.9.

Since there is a range of possible values for $e^*(\theta_h)$, there is not a unique equilibrium but a set of equilibria differing in the level of education obtained by the high-productivity. This set of separating equilibria can be ranked according to criterion of Pareto-preference. Clearly, changing the level of education $e^*(\theta_h)$ within the specified range does not affect the low-productivity workers. However, the high-productivity workers always prefer a lower level of education, since education is costly. Therefore equilibria with lower $e^*(\theta_h)$ are Pareto-preferred, and the most preferred equilibrium

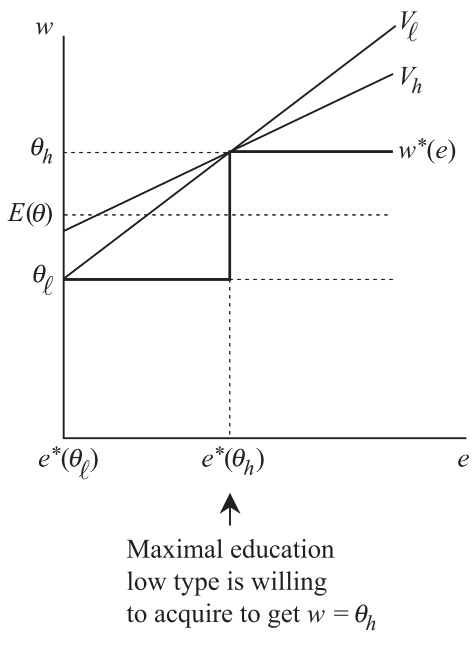

Figure 10.9
Separating equilibrium

is that with $e^*(\theta_h) = \theta_\ell [\theta_h - \theta_\ell]$. The Pareto-dominated separating equilibria are supported by the high-productivity worker's fear that choosing less education will give an unfavorable impression of their productivity to the firm and thus lead to a lower wage.

There are arguments (called refinements of equilibrium) to suggest that this most-preferred equilibrium will actually be the one that emerges. Let the equilibrium level of education for the high-productivity type, $e^*(\theta_h)$, be above the minimum required to separate. Denote this minimum e^0. Now consider the firm observing a worker with an education level at least equal to e^0 but less than $e^*(\theta_h)$. What should a firm conclude about this worker? Clearly, the worker cannot be low-productivity, since such a choice is worse for them than choosing no education. Hence the firm must conclude that the worker is of high productivity. Realizing this, it then pays the worker to deviate, since it would reduce the cost of an education. This argument can be repeated until $e^*(\theta_h)$ is driven down to e^0.

Signaling allows the high-productivity to distinguish themselves from the low-productivity. It might be thought that this improvement in information transmission would make signaling socially beneficial. However, this need not be the case, since the act of signaling is costly and does not add to productivity. The alternative to the signaling equilibrium is pooling where both types purchase no education and are paid a wage equal to the average productivity. The low-productivity would prefer this equilibrium as it raises their wage from θ_ℓ to $E(\theta) = \lambda_h\theta_h + \lambda_\ell\theta_\ell$. For the high-productivity pooling is preferred if

$$E(\theta) = \lambda_h\theta_h + \lambda_\ell\theta_\ell > \theta_h - \frac{\theta_\ell [\theta_h - \theta_\ell]}{\theta_h}. \tag{10.23}$$

Since $\lambda_\ell = 1 - \lambda_h$, this inequality will be satisfied if

$$\lambda_h > 1 - \frac{\theta_\ell}{\theta_h}. \tag{10.24}$$

Hence, when there are sufficiently many high-productivity workers so that the average wage is close to the high productivity level, the separating equilibrium is Pareto-dominated by the pooling equilibrium. In these cases signaling is individually rational but socially unproductive. Again, the Pareto-dominated separating equilibrium is sustained by the high-productivity workers' fear that lowering their education would give a bad impression of their ability to the firms and thus lead to lower wage. Actually the no-signaling pooling equilibrium is not truly available to the high-productivity workers.

If they get no education, firms will believe they are low-productivity workers and then offer a wage of θ_ℓ. So we get the paradoxical situation that high-productivity workers choose to signal, although they are worse off when signaling.

If the government were to intervene in this economy, it has two basic policy options. The first is to allow signaling to occur but to place an upper limit on the level of education equal to $\theta_\ell [\theta_h - \theta_\ell]$. It might choose to do this in those cases where the pooling equilibrium does not Pareto-dominate the separating equilibrium. There is, though, one problem with banning signaling and enforcing a pooling equilibrium. The pooling equilibrium requires the firms to believe that all workers have the same ability. If the firms were to "test" this belief by offering a higher wage for a higher level of education, they would discover that the belief was incorrect. This is illustrated in figure 10.10. A low-productivity worker would be better off getting no education than getting education above e^* whatever the firm's belief and the resulting wage. Therefore the firm should believe that any worker choosing an education level above e^* has high productivity and should be offered a wage θ_h. But, if this is so, the high-productivity worker could do better than the pooling equilibrium by deviating to an education level slightly in excess of e^* to get a wage θ_h. Therefore the pooling equilibrium is unlikely, since it involves unreasonable beliefs from the firms.

10.6.2 Implications

The model of educational signaling shows how an unproductive but costly signal can be used to distinguish between quality levels through a set of self-supporting beliefs. There will be a set of Pareto-ranked equilibria with the lowest level of signal the most preferred. Although there is an argument that the economy must achieve the Pareto-dominating signaling equilibrium, it is possible that this may not happen. If it does not, the economy may become settled in a Pareto-inferior separating equilibrium. Even if this does not happen, it is still possible for the pooling equilibrium to Pareto-dominate the separating equilibrium. This will occur when the high-productivity workers are relatively numerous in the population, since in that case almost every worker is getting unproductive but costly education to separate themselves from the few bad workers.

There are several policy implications of these results. In a narrow interpretation, they show how the government can increase efficiency and make everyone better off by restricting the size of signals that can be transmitted. Alternatively, the government could improve the welfare of everyone by organizing a cross-subsidy from the good to the bad workers. This can take the form of a minimum wage for the low-productivity workers in excess of their productivity financed by wage limit for the high-productivity workers that is below their productivity. Notice that a ban on signaling is an extreme form of such cross-subsidization, since it forces the same wage for all. When the pooling equilibrium is Pareto-preferred, signals should be eliminated entirely. More generally, the model demonstrates how market solutions may endogenously arise to combat the problems of asymmetric information. These solutions can never remove the problems entirely—someone must be bearing the cost of improving information flows—and can even exacerbate the situation.

The basic problem for the government in responding to these kinds of problems is that it does not have a natural informational advantage over the private agents. In the model of education there is no reason to suppose that the government is any more able to tell the low-productivity workers from the high-productivity (in fact there is every reason to suspect that the firms would be better equipped to do this). Faced with these kinds of problems, the government would have little to offer beyond the cross-subsidization we have just mentioned.

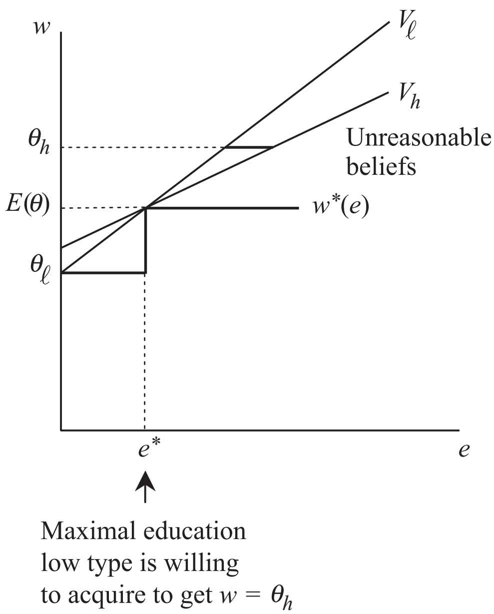

Figure 10.10
Unreasonable beliefs

10.7 Moral Hazard (Hidden Action)

A moral hazard problem arises when an agent can affect the "quality" of a traded good or contract variable by some action that is not observed by other agents. For instance, a houseowner once insured may become lax in her attention to security, such as leaving windows open, in the knowledge that if burgled she will be fully compensated. Or a worker, once in employment, may not fully exert himself, reasoning that his lack of effort may be hidden among the effort of the workforce as a whole. Such possibilities provide the motive for contracts to be designed that embody incentives to lessen these effects.

In the case of the worker, the employment contract could provide for a wage that is dependent on some measure of the worker's performance. Ideally the measure would be his exact productivity, but except for the simplest cases, this could be difficult to measure. Difficulties can arise because production takes place in teams (a production line can often be interpreted as a team) with the effort of the individual team member impossible to distinguish from the output of the team as a whole. They can also arise through randomness in the relation between effort and output. As examples, agricultural output is driven by the weather, maintenance tasks can depend on the (variable) condition of the item being maintained, and production can be dependent on the random quality of other inputs.

We now consider the design of incentive schemes in a situation with moral hazard. The model we choose embodies the major points of the previous discussion: effort cannot be measured directly, so a contract has to be based on some observable variable that roughly measures effort.

10.7.1 Moral Hazard in Insurance

The moral hazard problem that can arise in an insurance market is that effort on accident prevention is reduced when consumers become insured. If accident-prevention effort is costly, for instance, driving more slowly is time-consuming or eating a good diet is less enjoyable, then a rational consumer will seek to reduce such effort when it is beneficial to do so (and the benefits are raised once insurance is offered). Insurance companies must counteract this tendency through the design of their contracts.

To model this situation, assume an economy populated by many identical agents. The income of an agent is equal to r with probability $1 - p$ and $r - d$ with probability

p. Here p is interpreted as the probability of an accident occurring and d the monetary equivalent of the accident damage. Moral hazard is introduced by assuming that the agents are able to affect the accident probability through their prevention efforts.

To simplify, it is assumed that effort, e, can take one of two values. If $e = 0$, an agent is making no effort at accident prevention and the probability of an accident is $p(0)$. Alternatively, if $e = 1$, the agent is making maximum effort at accident prevention and the probability is $p(1)$. In line with these interpretations, it is assumed that $p(0) > p(1)$, so the probability of the accident is higher when no effort is undertaken. The cost of effort for the agents, measured in utility terms, is $c(e) \equiv ce$.

In the absence of insurance, the preferences of the agent are described by the expected utility function

$$U^o(e) = p(e)u(r - d) + (1 - p(e)))u(r) - ce, \tag{10.25}$$

where $u(r - d)$ is the utility if there is an accident and $u(r)$ is the utility if there is no accident. It is assumed that the agent is risk averse, so the utility function $u(\cdot)$ is concave.

The value of e, either 0 or 1, is chosen to maximize this utility. Effort to prevent the accident will be undertaken ($e = 1$) if

$$U^o(1) > U^o(0). \tag{10.26}$$

Evaluating the utilities and rearranging shows that $e = 1$ if

$$c \leq c_0 \equiv [p(0) - p(1)] [u(r) - u(r - d)] . \tag{10.27}$$

Here c_0 is the critical value of effort cost. If effort cost is below this value, effort will be undertaken. Therefore, in the absence of insurance, effort will be undertaken to prevent accidents if the cost of doing so is sufficiently small.

Consider now the introduction of insurance contracts. A contract consists of a premium π paid by the consumer and an indemnity δ, $\delta \leq d$, paid to the consumer if they are subject to an accident. The consumer's preferences over insurance policies (meaning different combinations of π and δ) and effort are given by

$$U(e, \delta, \pi) \equiv p(e)\, u\,(r - \pi + \delta - d) + [1 - p(e)]\, u(r - \pi) - ce, \tag{10.28}$$

with $U(e, 0, 0) = U^o(e)$.

10.7.2 Effort Observable

To provide a benchmark with which to measure the effects of moral hazard, we first analyze the choice of insurance contract when effort is observable by the insurance companies. In this case there can be no efficiency loss, since there is no asymmetry of information.

If the insurance company can observe e, it will offer an insurance contract that is conditional on effort choice. The contract will therefore be of the form $\{\delta(e), \pi(e)\}$, with $e = 0, 1$. Competition among the insurance companies ensures that the contracts on offer maximize the utility of a representative consumer subject to constraint that the insurance companies at least break even. To meet this latter requirement the premium must be no lower than the expected payment of indemnity. For a given e (recall this is observed) the policy therefore solves

$$\max_{\{\delta,\pi\}} U(e, \delta, \pi) \quad \text{subject to} \quad \pi \geq p(e)\,\delta. \tag{10.29}$$

The solution to this is a policy

$$\left\{\delta^*(e) = d,\ \pi^*(e) = p(e)d\right\}, \tag{10.30}$$

so that the damage is fully covered and the premium is fair given the effort level chosen. This is illustrated in figure 10.11. The straight line is the set of contracts that are fair (so $\pi = p(e)\,\delta$), and I is the highest indifference curve that can be achieved given these contracts. (Note that utility increases with a lower premium and greater coverage.) The first-best contract is therefore full insurance with $\delta^*(e) = d$ and $\pi^*(e) = p(e)d$.

At the first-best contract, the resulting utility level is

$$U^*(e) = u\,(r - p(e)d) - ce. \tag{10.31}$$

Effort will be undertaken ($e = 1$) if

$$U^*(1) \geq U^*(0), \tag{10.32}$$

which holds if

$$c \leq c_1 \equiv u(r - p(1)\,d) - u\,(r - p(0)\,d). \tag{10.33}$$

That is, the cost of effort is less than the utility gain resulting from the lower premium.

An interesting question is whether the first-best contract encourages the supply of effort, in other words, whether the level of effort cost below which effort is supplied in the absence of the contract, c_0, is less than that with the contract, c_1. Calculations show that the outcome may go in either direction depending on the accident probabilities associated with effort and no effort.

10.7.3 Effort Unobservable

When effort is unobservable, the insurance companies cannot condition the contract on it. Instead, they must evaluate the effect of the policies on the choices of the consumers and choose the policy taking this into account.

The preferences of the consumer over contracts are determined by the highest level of utility they can achieve with that contract, given that they have made the optimal choice of effort. Formally, the utility $V(\delta, \pi)$ arising from contract (δ, π) is determined by

$$V(\delta, \pi) \equiv \max_{\{e=0,1\}} U(e, \delta, \pi). \tag{10.34}$$

The basic analytical difficulty in undertaking the determination of the contract is the nonconvexity of preferences in the contract space (δ, π). This nonconvexity arises at the point in the contract space where the consumers switch from no effort ($e = 0$) to full effort ($e = 1$). When supplying no effort their preferences are determined by $U(0, \delta, \pi)$ and when they supply effort by $U(1, \delta, \pi)$. At any point $(\hat{\delta}, \hat{\pi})$ where $U(0, \hat{\delta}, \hat{\pi}) = U(1, \hat{\delta}, \hat{\pi})$, the indifference curve of $U(0, \hat{\delta}, \hat{\pi})$ is steeper than that of $U(1, \hat{\delta}, \hat{\pi})$ because the willingness to pay for extra coverage is higher when there is no

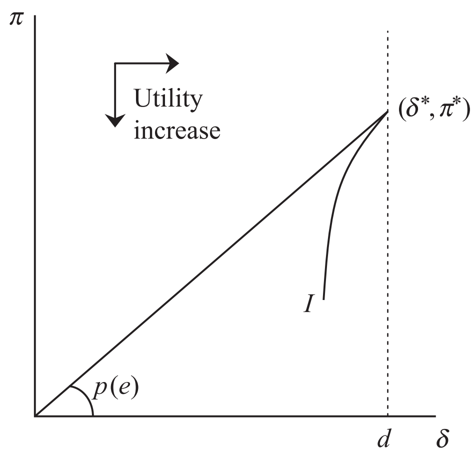

Figure 10.11
First-best contract

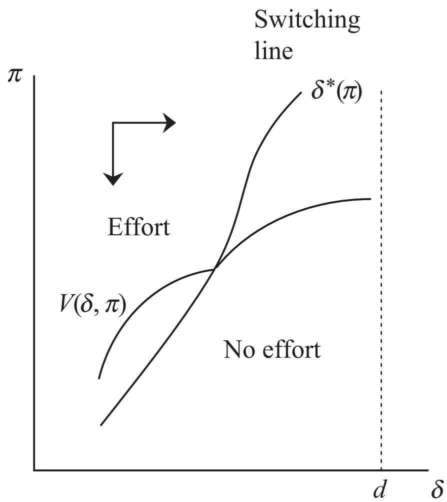

Figure 10.12
Switching line

effort and thus a high risk of accident. This is illustrated in figure 10.12, where $\delta^*(\pi)$ denotes the locus of points where the consumer is indifferent to $e = 0$ and $e = 1$. This locus separates those who make effort from those who make no effort. For each premium π, there is an indemnity level $\delta^*(\pi)$ such that if $\delta < \delta^*(\pi)$, then $e = 1$, but if $\delta \geq \delta^*(\pi)$, then $e = 0$. This indemnity level rises with the premium, so $\delta^*(\pi)$ is an increasing function of π. In words, if the coverage rate for any given premium is too high, agents will no longer find profitable to undertake effort.

10.7.4 Second-Best Contract

The second-best contract maximizes the consumer's utility subject to the constraint that it must at least break even. The optimization problem describing this can be written as that of maximizing $V(\delta, \pi)$ subject to the constraints that

(i) $\pi \geq p(1)\,\delta$ for $\delta < \delta^*(\pi)$,
(ii) $\pi \geq p(0)\,\delta$ for $\delta^*(\pi) \leq \delta < d$.

The first constraint applies if the consumer chooses to supply effort ($e = 1$) and requires that the contract break even. The second constraint is the break even condition if the consumer chooses to supply no effort ($e = 0$).

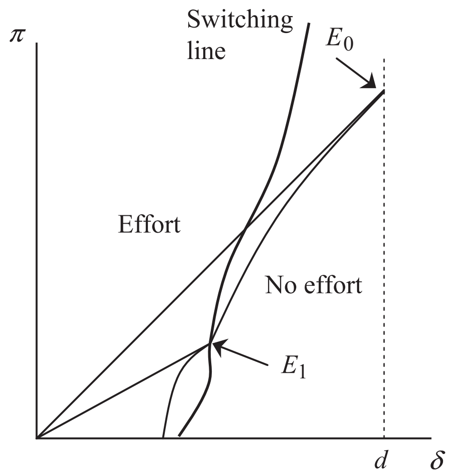

Figure 10.13
Second-best contract

The problem is solved by calculating the solution under the first constraint and evaluating the resulting level of utility. Then the solution is found under the second constraint and utility is evaluated again. The two levels of utility are then compared, and the one yielding the highest utility is the optimal second-best contract. This reasoning provides two contracts that are candidates for optimality. These are illustrated in figure 10.13 by E_0 and E_1 and have the following properties:

Contract E_0 No effort and full coverage at high price;
Contract E_1 Effort and partial coverage at low price.

Which of these contracts is optimal will depend on the cost, c, of effort. When this cost is low, contract E_1 will be optimal and partial coverage will be offered to consumers. Conversely, when the cost is high, then it will be optimal to have no effort and contract E_0 will be optimal. By this reasoning, it follows that there must be some value of the cost of effort at which the switch is made between E_0 and E_1. Hence there exists a value of effort, c_2, with $c_2 < c_1$, such that $c \leq c_2$ implies that the second-best contract is E_1 and $c > c_2$ implies that the second-best contract is E_0.

It can now be shown that the second-best contract is inefficient. Since the critical level of cost, c, determining when effort is supplied satisfies $c < c_1$, the outcome has to be inefficient relative to the first-best. Furthermore there is too little effort if $c_2 < c < c_1$ and too little coverage if $c < c_2$. These results are summarized in table 10.1.

Table 10.1
Categorization of outcomes

Cost of effort	c_2	c_1
1st best	Effort, full coverage	No effort, full coverage
2nd best	Effort, partial coverage	No effort, full coverage

10.7.5 Government Intervention

The market failure associated with moral hazard is very profound. The moral hazard problem arises from the nonobservability of the level of care. When individuals are fully insured they tend to exert too little precaution but also over-use insurance. Consider, for instance, a patient who may be either sick with probability 0.09 or very sick with probability 0.01. In the two events his medical expenses will be \$1,000 and \$10,000. At a fair premium of \$190 the patient will not have to pay anything if he gets sick and would buy such insurance if risk averse. But then suppose that when he is a little sick, there is some chance, however small, that he can be very sick. Then he would choose the expensive treatment given that there is no extra cost to the patient and all the extra cost is borne by the insurance company. Each individual ignores the effect of his reckless behavior and overconsumption on the premium, but when they all act like that, the premium increases. The lack of care by each inflates the premium, which generates a negative externality on others. An important implication is that the market cannot be efficient.

Another way to see this generic market inefficiency is that the provision of insurance in the presence of moral hazard causes the insured individual to receive less than the full social benefit of his care. As a result not only will the individual expend less than the socially optimal level of care but also there will be an insurance-induced externality.

This implies that the potential scope for government intervention with moral hazard is substantial. Can the government improve efficiency by intervention when moral hazard is present? In answering this question, it is important to specify what information is available to the government. For a fair evaluation of government intervention, it is natural to assume that the government has the same information as the private sector. In this case it can be argued that efficient government intervention is still possible. The beneficial effects of government intervention stem from the government's capacity to tax and subsidize. For example, the government cannot monitor smoking, which has an adverse effect on health, any better than an insurance company. But the government can impose taxes, not only on cigarettes but also on commodities that are complements and subsidize substitutes that have a less adverse effect. Also the taxation of insurance induces firms to offer insurance at less than fair price. As a consequence individuals buy less insurance and expend more effort (as efficiency requires).

10.8 Public Provision of Health Care

10.8.1 Efficiency

Economists do not expect the private market for health care insurance to function well. Our previous discussion suggests that informational problems result in the private provision of health insurance having incomplete and inefficient coverage. The existence of asymmetric information between insurers and insured leads to adverse selection, which can result in the market breaking down, and the nonexistence of certain types of insurance. The moral hazard problem can lead to incomplete insurance in the form of co-payments and deductibles for those who have insurance. Another problem caused by the presence of moral hazard is that the insured who become sick will want to overconsume and doctors will want to oversupply health care, since it is a third party that pays. It is not surprising therefore that the government may usefully intervene in the provision of health care.

There is strong evidence that in the OECD countries the public sector plays an important role in the provision of insurance for health care. From OECD health data, in 1994 the proportion of publicly provided health expenses was 44 percent in the United States, 70 percent in Germany, 73 percent in Italy, 75 percent in France, and 83 percent in Sweden and the United Kingdom. The question is why the government intervenes so extensively in the health care field. In answering the question, one must bear in mind that the government faces many of same informational problems as the private sector. Like a private insurer, it faces the moral hazard of patients who get insurance exerting too little effort in risk-reducing activities and overconsuming health services, and doctors having the incentive to oversupply health services at too high a cost.

One advantage of public provision is to prevent the adverse selection problem by making health coverage compulsory and universal. It is tempting to believe that the actual provision of insurance need not be public to accomplish this effect. Indeed the actual provision of health insurance could remain private and the government mandate that all individuals have to purchase health insurance and private insurers have to insure anyone who applies for insurance. However, mandates may be difficult to enforce at the individual level, and the incentive for private firms to accept only the good risks is a permanent concern. Another advantage of public provision is that as a predominant insurer it can exert monopsony power with considerable leverage over health suppliers in influencing the prices they set or the amount of services they prescribe.

The fact that private insurance is subject to the problem of moral hazard is less helpful in explaining government provision. Indeed it is questionable whether the government has any advantage in dealing with the problem of moral hazard, since it cannot observe the (hidden) activities of the insured any better than private insurers. One possible form of advantageous government intervention is the taxing and subsidizing of consumption choices that influence the insured's demand for health care (e.g., a subsidy for health club membership and taxes on smoking). This argument, as noticed by Prescott and Townsend (1984), is based on a presumption that the government can monitor these consumption choices better than the private market; otherwise, private insurers could condition contracts on their clients' consumption choices and the government would have no advantage over the market. So the potential scope for government provision with moral hazard is seemingly limited.

However, there is a more subtle form of moral hazard that provides a reason for direct government delivery of health care: the time-consistency problem. Imagine that health insurance is provided by the private sector only. Each individual must decide how much insurance to purchase. In a standard insurance situation, risk-averse individuals would fully insure if they could get a fair price. However, in this case they may recognize that if they do not fully insure, a welfaristic government will provide for them should they become ill and uninsured. They have thus an incentive to buy too little insurance and to rely on the government to finance their health care when they become sick. This phenomenon is called the *Samaritan's dilemma*, and it implies that people will underinvest resources available in the present, knowing that the truly welfaristic government will come to their rescue in the future. The problem is particularly acute for life-threatening diseases where denial of insurance is tantamount to a death sentence for the patient.

A similar time-consistency problem arises on the insurer's side: insurance companies cannot commit to guaranteeing that the rate charged for insurance will not change as they discover progressively more about the health conditions of their clients. Competition will force insurance companies to update their rate to reflect any new information about an individual's medical condition. Insurance could then become so expensive for some individuals that they could not afford it. With recent advances in genetic testing and other long-range diagnoses, this problem of the uninsured is likely to grow in the future. With no insurance against unfavorable test results or for the denial of insurance when a policy terminates, those more desperate to get insurance will find it increasingly hard to get it from the private market. The supply- and demand-side time-consistency problems were explicitly recognized in the United States by President Clinton, and used as a reason to make participation in health insurance compulsory. In response to the uninsured problem, the government provides a substitute for insurance by directly funding health care to the poor and long-term sick (Medicaid in the United States).

Another advantage of public provision of insurance is to achieve pooling on a much larger scale with improved risk-sharing. In including every person in a nationwide insurance scheme and pooling health insurance with other forms of insurance (unemployment, pension, etc.), public insurance comes closer to the "ideal" optimal insurance that requires the pooling of all the risks faced by individuals and a single contract covering them jointly (with a single deductible against all risks).

Both adverse selection and moral hazard have been central in the debates over health care reform in Europe and North America. Consider, for example, the debate about medical savings accounts (MSA) in the United States. These were intended to encourage people to buy insurance with more deductibles and co-payments, thereby reducing the risk of moral hazard. But critics argued that they will trigger a process of adverse selection where those less likely to need medical care will avail themselves of MSA. So those opting for the MSA with larger deductibles might indeed face higher total medical costs despite the improved incentives (they take more care), simply because of the self-selection process. Another response to moral hazard problems in the United States is the mandatory pre-admission referral by peer review organizations before hospitalization. The increasing popularity of health maintenance organizations can also be viewed as a response to moral hazard by attracting cost-conscious patients who wish to lower the cost of insurance. Finally the increasing use of co-payments in many countries appears to be the effective method of cost containment.

10.8.2 Redistributive Politics

Government provision not only requires mandatory insurance to eliminate the adverse selection problem, but it also involves socializing insurance. Once insurance is compulsory and financed (at least partly) by taxation, redistributive considerations play a central role in explaining the extensive public provision of insurance. Government programs that provide the same amount of public services to all households may still be redistributive. The amount of redistribution in fact depends on how the programs are financed and how valuable the services are to individuals with different income levels.

First, a public health care program offering services that are available to all and financed by a proportional income tax will redistribute income from the rich to the poor. If there is not too much diversity of tastes and if consumption of health care is independent of income, all those with incomes below the average are subsidized by those above the average. Given the empirical fact that a majority of voters have incomes below the average, a majority of voters would approve of public provision. With diversity of tastes, different individuals prefer different levels of consumption even when incomes are the same and the “one-size-fits-all” public provision may no longer be desirable for the majority. So the trade-off is between income redistribution and preference-matching. However, insofar as consumption of medical care is mostly the responsibility of doctors, reflecting standard medical practices, the preference-matching concern is likely to be negligible.

The second way that redistribution occurs is from the healthy to the sick (or the young to the aged). The tax payments of any particular individual do not depend on that individual’s morbidity. It follows that higher morbidity individuals receive insurance in the public system that is less expensive than the insurance they would get in the private market. So, if a taxpayer has either high morbidity or low income, then his tax price of insurance is lower than the price of private insurance. This taxpayer will vote for public provision. The negative correlation between morbidity and income suggests that the majority below average income are also more likely to be in relatively poor health and so in favor of public insurance.

The third route to redistribution is through opting-out. Universal provision of health care by the government can redistribute welfare from the rich to the poor because the rich refuse the public health care and buy higher quality private health services financed by private insurance. For example, individuals may have to wait to receive treatment in the public system, whereas private treatment is immediate. In opting-out, they lose the value of the taxes they pay toward public insurance, and the resources available for those who remain in the public sector increases as the overall pressure on the system decreases (i.e., the waiting list shortens). So redistribution is taking place because the rich are more likely to use private health care, even though free public health care is available. This redistribution will arise even if everyone contributes the same amount to public health insurance.

Redistribution via health care is also more effective in targeting some needy groups than redistribution in cash. The majority may wish to redistribute from those who inherit good health to those who inherit poor health, which can be thought of as a form of social insurance. If individual health status could be observed, the government would simply redistribute in cash, and there would be no reason for public health insurance. But, because it cannot observe an individual’s poor state of health, providing health care in-kind is a better way to target those individuals. The healthy individuals are less likely to pretend to be unhealthy when health care is provided in-kind than if government were to offer cash compensation to everyone claiming to be in poor health. This is the self-selection benefit of in-kind redistribution.

10.9 Evidence

Information asymmetries have significant implications for the working of competitive markets and the scope for government intervention. Detailed policy recommendations for alleviating these problems also differ depending on whether we face the adverse selection or moral hazard problems. It is crucial to test in different markets the empirical relevance of adverse selection and moral hazard. Such a test is surprisingly simple in the insurance market because both adverse selection and moral hazard predict a positive correlation between the frequency of accident and insurance coverage. This prediction turns out to be very general and to extend to a variety of more general contexts (imperfect competition, multidimensional heterogeneity, etc.).

The key problem is that such correlation can be given two different interpretations depending on the direction of the causality. Under adverse selection high-risk agents, knowing they are more likely to have an accident, self-select by choosing more extensive coverage. Alternatively, under moral hazard agents with more extensive coverage are also less motivated to exert precaution, which may result in higher accident rates. The difference matters a lot for health insurance if we want to assess the impact of co-payments and deductibles on consumption and its welfare implications. Indeed it is a well-documented fact that better coverage is correlated with higher medical expenses. Deductibles and co-payments are likely to be desirable if moral hazard is the main reason, since they reduce overconsumption. But, if adverse selection is the main explanation, then limiting coverage can only reduce the amount of insurance available to risk-averse agents with little welfare gain. Evidence on selection versus incentives can be tested in a number of ways, and we briefly describe some of them.

Manning et al. (1987) separate moral hazard from adverse selection by using a random experiment in which individuals are exogenously allocated to different contracts. Between 1974 and 1977 the Rand Health Insurance Experiment randomly assigned households in the United States to one out of 14 different insurance plans with different co-insurance rates and upper limits on annual out-of-pocket expenses. Compensation was paid in order to guarantee that no household would lose by participating in the experiment. Since individuals were randomly assigned to contracts, any differences in observed behavior can be interpreted as a response to the different incentive structures of the contracts. This experiment has provided some of the most interesting and robust tests of moral hazard and the sensitivity of the consumption of medical services to out-of-pocket expenditures. The demand for medical services was found to respond significantly to changes in the amount paid by the insuree. The largest decrease in the use of services arises between a free service and a contract involving a 25 percent co-payment rate.

Chiappori et al. (1998) exploit a 1993 change in French regulations to which health insurance companies responded by modifying their coverage rates in a non-uniform way. Some companies increased the level of deductibles, while others did not. They test for moral hazard by using groups of patients belonging to different companies who were confronted with different changes in co-payments and whose use of medical services was observed before and after the change in regulation. They find that the number of home visits by general practitioners significantly decreased for the patients who experienced the increase in co-payments but not for those whose coverage remained constant.

Another interesting study is by Cardon and Hendel (2001) who test for moral hazard versus adverse selection in the US employer-provided health insurance. As argued before, a contract with larger co-payments is likely to involve lower health expenditures, either because of the incentive effect of co-payments or because the high-risk self-select by choosing contracts with lower co-payments. The key identifying argument is that agents do not select their employer on the basis of the health insurance coverage. As a consequence the differences in behavior across employer plans can be attributed to incentive effects. They find strong evidence that incentives matter.

Another way to circumvent the difficulty in empirically distinguishing between adverse selection and moral hazard is to consider the annuity market. The annuity market provides insurance against the risk of outliving accumulated resources. It is more valuable to those who expect to live longer. In this market we can safely expect that individuals will not substantially modify their behavior in response to annuity income (e.g., exerting more effort to extend length of life). It follows that differential mortality rates for annuitants who purchase different types of annuities is convincing evidence that selection occurs. Finkesltein and Poterba (2004) obtain evidence of the following selection patterns: First, those who buy back-loaded annuities (annuities where payments increase over time) are longer-lived (controlling for all observables) than other annuitants, which is consistent with the fact that an annuitant with a longer life expectancy is more likely to be alive in later years when the back-loaded annuity pays out more than the flat annuity. Second, those who buy annuities making payments to the estate are shorter-lived than other annuitants, which is consistent with the fact that the possibility of payments to a short-lived annuitant.

10.10 Conclusions

The efficiency of competitive equilibrium is based on the assumption of symmetric information (or the very strong requirement of perfect information). This chapter has explored some of the consequences of relaxing this assumption. The basic points are that asymmetric information leads to inefficiency and that the inefficiency can take a number of different forms.

Under certain circumstances appropriate government intervention can make everyone better off, even though the government does not have better information than the private sector. The role of the government may also be limited by restrictions on its information. Welfare and public policy implications of the two main forms of information asymmetries are not the same, and it has been an empirical challenge to distinguish between adverse selection and moral hazard. Health insurance is a good illustration of the problems that arise and is characterized by extensive public intervention.

Further Reading

The main contributions on asymmetric information are:

Akerlof, G. 1970. The market for lemons: Quality uncertainty and the market mechanism. *Quarterly Journal of Economics* 89: 488–500.

Arrow, K. J. 1963. Uncertainty and the welfare economics of medical care. *American Economic Review* 53: 942–73.

Greenwald, B., and Stiglitz, J. E. 1986. Externalities in economies with imperfect information and incomplete markets. *Quarterly Journal of Economics* 100: 229–64.

Prescott, E., and Townsend, R. 1984. Pareto optima and competitive equilibrium with adverse selection and moral hazard. *Econometrica* 52: 21–46.

Rothschild, M., and Stiglitz, J. E. 1976. Equilibrium in competitive insurance markets: An essay in the economics of imperfect information. *Quarterly Journal of Economics* 80: 629–49.

Spence, M. 1973. Job market signaling. *Quarterly Journal of Economics* 87: 355–74.

Spence, M. 1974. *Market Signaling*. Cambridge: Harvard University Press.

A simple exposition of the moral hazard problem is in:

Arnott, R., and Stiglitz, J. E. 1988. The basic analytics of moral hazard. *Scandinavian Journal of Economics* 90: 383–413.

Applications of the self-selection concept in redistribution programs are:

Besley, T., and Coate, S. 1991. Public provision of private goods and the redistribution of income. *American Economic Review* 81: 979–84.

Blackorby, C., and Donaldson, D. 1988. Cash versus kind, self-selection, and efficient transfers. *American Economic Review* 78: 691–700.

Bruce, N., and Waldman, M. 1991. Transfer in kind: Why they can be efficient and nonpaternalistic. *American Economic Review* 81: 1345–51.

Buchanan, J. 1975. The Samaritan's Dilemma. In E. S. Phelps, ed., *Altruism, Morality and Economic Theory*. New York: Russell Sage Foundation.

Applications to health insurance are:

Besley, T., and Gouveia, M. 1994. Alternative systems of health care provision. *Economic Policy* 19: 199–258.

Cardon, J., and Hendel, I. 2001. Asymmetric information in health insurance: Evidence from the national health expenditure survey. *Rand Journal of Economics* 32: 408–27.

De Donder, P., and Hindriks, J. 2003. The politics of redistributive social insurance. *Journal of Public Economics* 87: 2639–60.

Poterba, J. 1994. Government intervention in the markets for education and health care: How and why? NBER Working Paper 4916.

Usher, D. 1977. The welfare economics of the socialization of commodities. *Journal of Public Economics* 8: 151–68.

Empirical testing of adverse selection and moral hazard is in:

Chiappori, P. A., Durand, F., and Geoffard, P. Y. 1998. Moral hazard and the demand for physicians services: First lessons from a French natural experiment. *European Economic Review* 42: 499–511.

Chiappori, P. A., and Salanie¨, B. 2003. Testing contract theory: A survey of some recent works. In M. Dewatripont, L. Hansen, and S. Turnovsky, eds., *Advances in Economics and Econometrics*, vol. 1. Cambridge: Cambridge University Press, 115–49.

Finkesltein, A., and Poterba, J. 2004. Adverse selection in insurance markets: Policyholder evidence from the UK annuity market. *Journal of Political Economy* 112: 183–208.

Manning, W., Newhouse, J., Duan, N., Keeler, E., and Leibowitz, A. 1987. Health insurance and the demand for medical care: Evidence from the randomized experiment. *American Economic Review* 77: 257–77.

Exercises

10.1 What is fair insurance? Why will a risk-averse consumer always buy full insurance when it is fair insurance?

10.2 Should the government allow insurance companies to use genetic testing to better assess the health status of their applicants? Would this genetic testing help or hurt those who are in bad health? Would it exacerbate or mitigate the problem of adverse selection in the health insurance market? Would it increase or decrease the number of people without health insurance? Would it be a good thing?

10.3 Are the following statements true or false?

a. An insurance company must be concerned about the possibility that someone will buy fire insurance on a building and then set fire to it. This is an example of moral hazard.

b. A life insurance company must be concerned about the possibility that the people who buy life insurance may tend to be less healthy than those who do not. This is an example of adverse selection.

c. In a market where there is separating equilibrium, different types of agents make different choices of actions.

d. Moral hazard refers to the effect of an insurance policy on the incentives of individuals to exercise care.

e. Adverse selection refers to how the magnitude of the insurance premium affects the types of individuals that buy insurance.

10.4 Consider each of the following situations involving moral hazard. In each case identify the principal (uninformed party) and the agent (informed party) and explain why there is asymmetric information. How does the action described for each situation mitigate the moral hazard problem?

a. Car insurance companies offer discounts to customers who install anti-theft and speed-monitoring devices in their cars.

b. The International Monetary Fund conditions lending to developing countries upon the adoption of a structural adjustment plan.

c. Firms compensate top executives with options to buy company stock at a given price in the future.

d. Landlords require tenants to pay security deposits.

10.5 Despite the negative stereotype of "women drivers," women under age of 25 are, on average, noticeably better drivers than men under 25. Consequently insurance companies have been willing to offer young women insurance with a discount of 60 percent over what they charge young men. Similar discrimination applies on the life insurance market given that women are expected to live longer. Sex-based discrimination for auto and life insurance is extremely controversial. Many people have argued that sex-based rates constitute unfair discrimination. After all, some men live longer than some women, and there are some men who are better drivers than some women. In response, several US states have laws mandating "unisex" insurance ratings.

a. What are the likely effects of such interference with the market forces?

b. Should the government allow insurance companies to base life insurance rates on sex? What are the risks for women and for men who were paying very different rates? Who gains and who loses?

c. Should insurance companies be allowed to base automobile insurance rates on sex, age, and marital status? What are the consequences of having some groups paying much less than they would if rates were based on actuarial differences in accident rates across sexes and ages?

10.6 Consider a community of individuals that have different probabilities of falling ill. Individuals of type H have a probability of falling ill of $p^H = 0.6$. These individuals form $\frac{3}{4}$ of the population. Individual of type L, the remaining $\frac{1}{4}$ of the population, have a probability of falling ill of $p^L = 0.2$. Any individual who is ill suffers an income loss of 200.

a. Assume there is symmetric information. What is the actuarially fair premium for the each group to insure againt illness? What level of coverage will each individual request if offered insurance at the actuarially fair premium?

b. Assume that there is asymmetric information and firms cannot distinguish between the types. The same insurance contract must be offered to all individuals. If the contract is to earn an expected profit of zero, what premium must be charged?

c. Is it possible for a firm to offer an alternative contract that is profitable when the contract in part b is available?

10.7 Discuss the argument that paying for human blood has the effect of lowering its average quality because people who are driven by the profit motive to provide blood are more likely to be drug addicts, alcoholics, and have serious infectious diseases than are voluntary donors.

10.8 In California many insurance companies charge different rates depending on what part of the city you live in. Their rationale is that risk factors like theft, vandalism, and traffic congestion vary greatly from one place to the other. The result is that people who live close to each other, but in adjacent zip codes, may end up paying very different insurance premia.

a. What would happen to an insurance company that decided to sell insurance at the same price to all drivers with the same driving records no matter what part of the city they live in?

b. What would happen if the government decides to outlaw geographic rate differentials, given that the government cannot force private insurance companies to provide insurance against their will?

10.9 Georgie has a labor income equal to 100. With probability $p = 0.25$, she will have an accident during the year and suffer an income loss equal of 60. With probability $p = 0.75$, she will have no accident. Georgie decides to purchase insurance contract to cover the loss of income if she has an accident.

a. What is the actuarially fair premium for the insurance? What level of coverage will Georgie buy?

Georgie loves extreme sports and fast driving. If insured, she will drive faster and try more extreme activities. This increases her risk of accident. Let the risk be given by $p = 1 - \frac{L}{80}$, where L is the uninsured income loss.

b. Will the contract in part a break even? If the insurance company knows Georgie's behavior (the function $p = 1 - \frac{L}{80}$), what contract will it offer? If the insurance company does not know her behavior, what contract will break even?

10.10 The European Union has made discrimination between males and females illegal for insurance contracts. Explain the effects of this decision. Will it benefit anyone?

10.11 The local government has hired someone to undertake a public project. If the project fails, it will lose \$20,000. If it succeeds, the project will earn \$100,000. The employee can choose to "work" or to "shirk." If she shirks, the project will fail for sure. If she works, the project will succeed half of the time but will still fail half of the time. The employee's utility is \$10,000 lower if she works than if she shirks. In addition the employee could earn \$10,000 in another job (where she would shirk). The government is choosing whether to pay the employee a flat wage of $20,000 (no matter how the project turns out) or performance-related pay under which the employee earns 0 if the project fails and $40,000 if it succeeds.

a. Assuming that both parties are risk neutral, which compensation scheme should the government use?

b. Do you see any problem with the performance-related pay scheme when the employee is risk averse?

10.12 Use the signaling model presented in section 10.6 to construct an example in which a government unaware of workers' productivities can improve the welfare of everyone compared to the (best) separating equilibrium by means of a cross-subsidization policy but not by banning signaling.

10.13 A firm hires two kinds of workers, alphas and betas. One can't tell a beta from an alpha by looking at her, but an alpha will produce $3,000 worth of output per month and a beta will produce $2,500 worth of output in a month. The firm decides to distinguish alphas from betas by making them pass an examination. For each question that they get right on the exam, alphas have to spend half an hour studying and betas have to spend one hour. A worker will be paid $3,000 if she gets at least 40 answers right and $2,500 otherwise. For either type, an hour of studying is as bad as giving up $20 income. What is the equilibrium of this scheme?

10.14 Consider a loan market to finance investment projects. All projects cost 1. Any project is either good (with probability ρ) or bad (with probability $1-\rho$). Only investors know whether their project is good or bad. A good project yields profits of $\pi > 0$ with probability P_g and no profit with probability $1 - P_g$. A bad project makes profits of π with a lower probability P_b (with $P_b < P_g$) and no profit with a higher probability $1 - P_b$. Banks are competitive and risk neutral, which implies that banks offer loan contracts making expected profits of zero. A loan contract specifies a repayment R that is supposed to be repaid to the bank only if the project makes profit; otherwise, the investor defaults on her loan contract. The opportunity cost of funds to the bank is $r > 0$. Suppose

$$P_g - (1+r) > 0 > P_b - (1+r).$$

a. Find the equilibrium level of R and the set of projects financed. How does this depend on P_g, P_b, ρ, π, and r?

b. Now suppose that the investor can signal the quality of her project by self-financing a fraction of the project. The opportunity cost of funds to the investor is s (with $s > r$ implying a costly signal). Describe the investor's payoff as a function of the type of her project, the loan repayment R and her self-financing rate. Derive the indifference curve for each type of investor in the (s, R) space. Show that the single-crossing property holds.

c. What is the best separating equilibrium of the signaling game where the investor first chooses s and banks then respond by a repayment schedule $R(s)$? How does the self-financing rate of good projects change with small changes of P_g, P_b, ρ, π, and r?

d. Compare this (best) separating equilibrium with part a.

10.15 (Akerlof) Consider the following market for used cars. There are many sellers of used cars. Each sellers has exactly one used car to sell and is characterized by the quality of the used car he wishes to sell. Let θ, $0 \leq \theta \leq 1$, index the quality of a used car, and suppose that θ

is uniformly distributed on the interval [0, 1]. If a seller of type θ sells his car at price p, his utility is $u_s(p, \theta)$. With no sale his utility is 0. Buyers receive utility $\theta - p$ if they buy a car of quality θ at price p, and receive utility 0 if they do not purchase. The quality of the car is only known to sellers, and there are enough cars to supply all potential buyers.

a. Explain why the competitive equilibrium outcome under asymmetric information requires that the average quality of cars that are put for sale conditional on price is just equal to price, $E(\theta | p) = p$. Describe the equilibrium outcome in words. In particular, describe which cars are traded in equilibrium.

b. Show that if $u_s(p, \theta) = p - \frac{\theta}{2}$, then every price $0 < p \leq \frac{1}{2}$ is an equilibrium price.

c. Find the equilibrium price when $u_s(p, \theta) = p - \sqrt{\theta}$.

d. How many equilibrium prices are there when $u_s(p, \theta) = p - \theta^3$?

e. Which (if any) of the preceding outcomes are Pareto-efficient? Describe Pareto improvements whenever possible.

10.16 It is known that some fraction d of all new cars are defective. Defective cars cannot be identified as such except by those who own them. Each consumer is risk neutral and values a nondefective car at \$16,000. New cars sell for \$14,000 each, and used ones for \$2,000. If cars do not depreciate physically with use, what is the proportion d of defective new cars?

10.17 In the preceding question, assume that new cars sell for \$18,000 and used cars sell for \$2,000. If there is no depreciation and risk-neutral consumers know that 20 percent of all new cars are defective, how much do the consumers value a nondefective car?

10.18 There are two types of jobs in the economy, good and bad, and two types of workers, qualified and unqualified. The population consists of 60 percent qualified and 40 percent unqualified. In a bad job, either type of worker produces the same 10 units of output. In a good job, a qualified worker produces 100 and an unqualified worker produces 0. There are numerous job openings of each type, and companies must pay for each type of job what they expect the appointee to produce. The worker's type is unknown before hiring, but the qualified workers can signal their type (e.g., by getting educated or some other means). The cost of signaling to level s for a qualified worker is $\frac{s^2}{2}$ and for an unqualified worker is s^2. The signaling costs are measured in the same units as output, and s must be an integer (e.g., number of years of education).

a. What is the minimum level of s that will achieve separation?

b. Suppose that the signal is no longer available. Which kinds of job will be filled by which types of workers, and at what wages? Who gains and who loses?

10.19 The government can help those people most in need by either giving them cash or providing free meals. What is the argument for giving cash? What kind of argument based on asymmetric information could support the claim that free meals (an in-kind transfer) are better than the cash handout? Can such an argument apply to free education?

10.20 Explain why an automaker's willingness to offer a resale guarantee for its cars may serve as a signal of their quality.

10.21 A competitive market for annuity contracts has a number of risk-neutral providers. There are two time periods. There are also two types of individual ($i = L, H$) that vary only in their probabilities, ρ_H and ρ_L, of surviving (life expectency) to live in the second period. Assume $\rho_H > \rho_L$. Unlike the firms, the individuals know their types exante. The distribution of types is commonly known where $\gamma \in (0, 1)$ denotes the proportion of the L-type in the population.

a. Let a_i denote the value of annuities bought by individual i and q_i the return on annuities. Moreover the interest rate, r, satisfies $r = 0$ (there is no discounting) and the income of the first period is w for both types. Derive the intertemporal budget of an individual.

b. The utility function is given by

$$EUi = -\left(c_1^i\right)^{-1} - \rho_i \left(c_2^i\right)^{-1}, \qquad i = L, H.$$

Show that the indifference curves of both types intersect exactly once. Explain this intuitively.

c. Suppose $w = 10, \rho_H = \frac{1}{2}$ and $\rho_L = \frac{1}{4}$. Determine the first-best solution, meaning the solution in the case where the firms are able to distinguish the types. Which type would have an incentive to deviate?

d. Suppose that there exists a separating equilibrium. Derive the optimal solution (a_H, c_1^H, c_2^H). Give an intuitive explanation for your result.

e. Assume $w = 10$, $\rho_H = \frac{1}{2}$ and $\rho_L = \frac{1}{4}$. Determine c_1^L and c_2^L in the separating equilibrium.

How do c_1^L and c_2^L change if ρ_H marginally rises?

f. Explain intuitively how the separating equilibrium depends on ρ.Show graphically how you could find the critical γ for which the separating equilibrium of parts d and e does not exist anymore.

10.22 The design of the health care system involves issues of information at several points. The potential users (patients) are better informed about their own state of health and lifestyle than insurance companies. The health providers (doctors and hospitals) know more about what patients need than do either the patients themselves or the insurance companies. Providers also know more about their own skills and efforts. Insurance companies have statistical information about outcomes of treatments and surgical procedures from past records. The drug companies know more about the efficacy of drugs than do others. As is usual, the parties have different interests, so they do not have a natural inclination to share their information fully or accurately with others.

a. From this perspective, consider the relative merits of the following payments schemes:

i. A fee for service versus capitation fees to doctors.

ii. Comprehensive premiums per year versus payment for each visit for patients.

b. Which payments schemes are likely to be most beneficial to the patients and which to the providers?

c. What are the relative merits of private insurance compared to coverage of costs from general tax revenues?