

Markets with Asymmetric Information

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For more than two decades, research on incentives and market equilibrium in situations with asymmetric information has been a prolific part of economic theory. In 1996, the Bank of Sweden Prize in Economic Sciences in Memory of Alfred Nobel was awarded to James Mirrlees and William Vickrey for their fundamental contributions to the theory of incentives under asymmetric information, in particular its applications to the design of optimal income taxation and resource allocation through different types of auctions. The theory of markets with asymmetric information rests firmly on the work of three researchers: George Akerlof (University of California, Berkeley), Michael Spence (Stanford University) and Joseph Stiglitz (Columbia University). Their pioneering contributions have given economists tools for analyzing a broad spectrum of issues. Applications extend from traditional agricultural markets to modern financial markets.¹

Why are interest rates often so high on local lending markets in Third World countries? Why do people looking for a good used car typically turn to a dealer rather than a private seller? Why do firms pay dividends even if they are taxed more heavily than capital gains? Why is it in the interest of insurance companies to offer a menu of policies with different mixes of premiums, coverage and deductibles? Why do wealthy landowners not bear the entire harvest risk in contracts with poor tenants? These questions exemplify familiar – but seemingly different – phenomena, each of which posed a challenge to traditional economic theory. This year’s laureates showed that these – and many other – phenomena can be understood by augmenting the theory with the same realistic assumption: one side of the market has better information than the other. The borrower knows more than the lender about his creditworthiness; the seller knows more than the buyer about the quality of his car; the CEO and board of a firm know more than the shareholders about the profitability of the firm; insurance clients know more than the insurance company about their accident risk; and tenants know more than the landowner about harvesting conditions and their own work effort.

¹See Riley (2001) for a survey of developments in the economics of information over the last 25 years.

More specifically, the contributions of the prizewinners may be summarized as follows. Akerlof showed how informational asymmetries can give rise to *adverse selection* in markets. When lenders or car buyers have imperfect information, borrowers with weak repayment prospects or sellers of low-quality cars may thus crowd out everyone else from their side of the market, stifling mutually advantageous transactions. Spence demonstrated that informed economic agents in such markets may have incentives to take observable and costly actions to credibly *signal* their private information to uninformed agents, so as to improve their market outcome. The management of a firm may thus incur the additional tax cost of dividends, so as to signal high profitability. Stiglitz showed that poorly informed agents can indirectly extract information from those who are better informed, by offering a menu of alternative contracts for a specific transaction, so-called *screening* through self-selection. Insurance companies are thus able to divide their clients into risk classes by offering different policies where, say, lower premiums can be exchanged for higher deductibles. Stiglitz also analyzed a range of similar mechanisms in other markets.

Akerlof, Spence and Stiglitz's analyses form the core of modern information economics. Their work transformed the way economists think about the functioning of markets. The analytical methods they suggested have been applied to explain many social and economic institutions, especially different types of contracts. Other researchers have used and extended their original models to analyze organizations and institutions, as well as macroeconomic issues, such as monetary and employment policy.

Sections 1 through 3 below give a brief account of the most fundamental contributions by the laureates. Section 4 describes some applications and empirical tests of their models. Suggestions for further reading and a list of references are given at the end.

1. GEORGE AKERLOF

Akerlof's article, "The Market for Lemons: Quality Uncertainty and the Market Mechanism" (Akerlof, 1970), is probably the single most important contribution to the literature on economics of information. This paper has all the typical features of a truly seminal piece. It introduces a simple but profound and universal idea, offers numerous interesting implications and points to broad applications. Nowadays, Akerlof's insights regarding adverse selection are routinely taught in microeconomics courses at the undergraduate level.² His essay analyzes a market for a product where

²More recently, the term "private information" or "hidden information" has become increasingly common in describing such situations. Those terms say more about the causes of the phenomenon whereas "adverse selection" emphasizes its consequences.

sellers are better informed than buyers about the quality of the good; one example is the market for used cars. Since then, “lemons” (a colloquialism for defective cars) has become a well-known metaphor in every economist’s vocabulary.

Akerlof’s idea may be illustrated by a simple example. Assume that a good is sold in indivisible units and is available in two qualities, low and high, in fixed shares λ and $1 - \lambda$. Each buyer is potentially interested in purchasing one unit, but cannot observe the difference between the two qualities at the time of the purchase. All buyers have the same valuation of the two qualities: one unit of low quality is worth w^L dollars to the buyer, while one high-quality unit is worth $w^H > w^L$ dollars. Each seller knows the quality of the units he sells, and values low-quality units at $v^L < w^L$ dollars and high-quality units at $v^H < w^H$ dollars.

If there were separate markets for low and high quality, every price between v^L and w^L would induce beneficial transactions for both parties in the market for low quality, as would every price between v^H and w^H in the market for high quality. This would amount to a socially efficient outcome: all gains from trade would be realized. But if the markets are not regulated and buyers cannot observe product quality, unscrupulous sellers of low-quality products would choose to trade on the market for high quality. In practice, the markets would merge into a single market with one and the same price for all units. Suppose that this occurs and that the sellers’ valuation of high quality exceeds the consumers’ average valuation. Algebraically, this case is represented by the inequality $v^H > \bar{w}$, where $\bar{w} = \lambda w^L + (1 - \lambda)w^H$. If trade took place under such circumstances, the buyers’ (rational) expectation of quality would be precisely \bar{w} . In other words, the market price could not exceed \bar{w} (assuming that consumers are risk averse or risk neutral). Sellers with high-quality goods would thus exit from the market, leaving only an adverse selection of low-quality goods, the lemons.³

In his paper, Akerlof not only explains how private information may lead to the malfunctioning of markets. He also points to the frequency with which such informational asymmetries occur and their far-reaching consequences. Among his examples are social segregation in labor markets and difficulties for elderly people in buying individual medical insurance. Akerlof emphasizes applications to developing countries. One of his examples of adverse selection is drawn from credit markets in India

³Classical economic analysis disregarding asymmetric information would misleadingly predict that goods of both qualities would be sold on the market, at a price close to the consumers’ average valuation.

A very early prototype of Akerlof’s result is usually referred to as Gresham’s law: “bad money drives out good”. (Thomas Gresham, 1519-1579, was an adviser to Queen Elisabeth I on currency matters.) But as Akerlof (1970, p. 490) himself points out, the analogy is somewhat lame; in Gresham’s law both sellers and buyers can presumably distinguish between “good” and “bad” money.

in the 1960s, where local moneylenders charged interest rates that were twice as high as the rates in large cities. However, a middleman trying to arbitrage between these markets without knowing the local borrowers' creditworthiness, risks attracting those with poor repayment prospects and becomes liable to heavy losses.

Another fundamental insight is that economic agents' attempts to protect themselves from the adverse consequences of informational asymmetries may explain existing institutions. Guarantees made by professional dealers in the used-car market is but one of many examples. In fact, Akerlof concludes his essay by suggesting that "this (adverse selection) may indeed explain many economic institutions". This prophecy has come true; his approach has generated an entire literature analyzing how economic institutions may mitigate the consequences of asymmetric information.

In a later article, "The Economics of Caste and the Rat Race and Other Woeful Tales" (Akerlof, 1976), Akerlof enters into a more thorough discussion of the significance of informational asymmetries in widely differing contexts, such as the caste system, factory working conditions and sharecropping. He uses illustrative examples to show how certain variables, called "indicators", not only provide important efficiency-enhancing economic information, but may also cause the economy to become trapped in an undesirable equilibrium. In the case of sharecropping, where tenancy is repaid by a fixed share of the harvest, a tenant's volume of production acts as an indicator of his work effort on the farm. On the assembly line in a factory, the speed of the conveyor belt acts as an indicator of the workers' ability, and can therefore be used as an instrument to distinguish between workers of different abilities.

Apart from his work on asymmetric information, Akerlof has been innovative in enriching economic theory with insights from sociology and social anthropology. Several of his papers on the labor market have examined how emotions such as "reciprocity" towards an employer and "fairness" towards colleagues can contribute to higher wages and thereby unemployment; see Akerlof (1980, 1982) and Akerlof and Yellen (1990). This kind of emotionally motivated behavior has recently been confirmed experimentally, see e.g., Fehr and Schmidt (1999, 2000), and has also received empirical support from interview surveys, see e.g., Bewley (1999).

2. MICHAEL SPENCE

Spence's most important work demonstrates how agents in a market can use signaling to counteract the effects of adverse selection. In this context, signaling refers to observable actions taken by economic agents to convince the opposite party of the value or quality of their products. Spence's main contributions were to develop and

formalize this idea and to demonstrate and analyze its implications.⁴ A fundamental insight is that signaling can succeed only if the signaling cost differs sufficiently among the “senders”. Subsequent research contains many applications which extend the theory of signaling and confirm its importance in different markets.

Spence’s seminal paper “Job Market Signaling” (Spence, 1973) and book *Market Signaling* (Spence, 1974) both deal with education as a signal in the labor market. If an employer cannot distinguish between high- and low-productivity labor when hiring new workers, the labor market might collapse into a market where only those with low productivity are hired at a low wage – this is analogous to the adverse-selection outcome in Akerlof’s market where only lemons remain.

Spence’s analysis of how signaling may provide a way out of this situation can be illustrated by slightly extending Akerlof’s simple example above. Assume first that job applicants (the “sellers”) can acquire education before entering the labor market. The productivity of low-productivity workers, w^L , is below that of high-productivity workers, w^H and the population shares of the two groups are λ and $1 - \lambda$, respectively. Although employers (the “buyers”) cannot directly observe the workers’ productivity, they can observe the workers’ educational level. Education is measured on a continuous scale, and the necessary cost – in terms of effort, expenses or time – to reach each level is lower for high-productivity individuals. To focus on the signaling aspect, Spence assumes that education does not affect a worker’s productivity, and that education has no consumption value for the individual. Other things being equal, the job applicant thus chooses as little education as possible. Despite this, under some conditions, high-productivity workers will acquire education.⁵

Assume next that employers expect all job applicants with at least a certain educational level $s^H > 0$ to have high productivity, but all others to have low productivity. Can these expectations be self-fulfilling in equilibrium? Under perfect competition and constant returns to scale, all applicants with educational level s^H or higher are offered a wage equal to their expected productivity, w^H , whereas those with a lower educational level are offered the wage w^L . Such wage setting is illustrated by the step-wise schedule in *Figure 1*. Given this wage schedule, each job applicant will choose either the lowest possible education $s^L = 0$ obtaining the low wage w^L , or the higher educational level s^H and the higher wage w^H . An education between these levels does not yield a wage higher than w^L , but costs more; similarly, an education above s^H does not yield a wage higher than w^H , but costs more.

In *Figure 1* job applicants’ preferences are represented by two indifference curves,

⁴Informal versions of this idea can be traced to the sociological literature; see Berg (1970).

⁵Obviously, job applicants’ incentives to acquire education will be strengthened under the more realistic assumption that education enhances productivity.

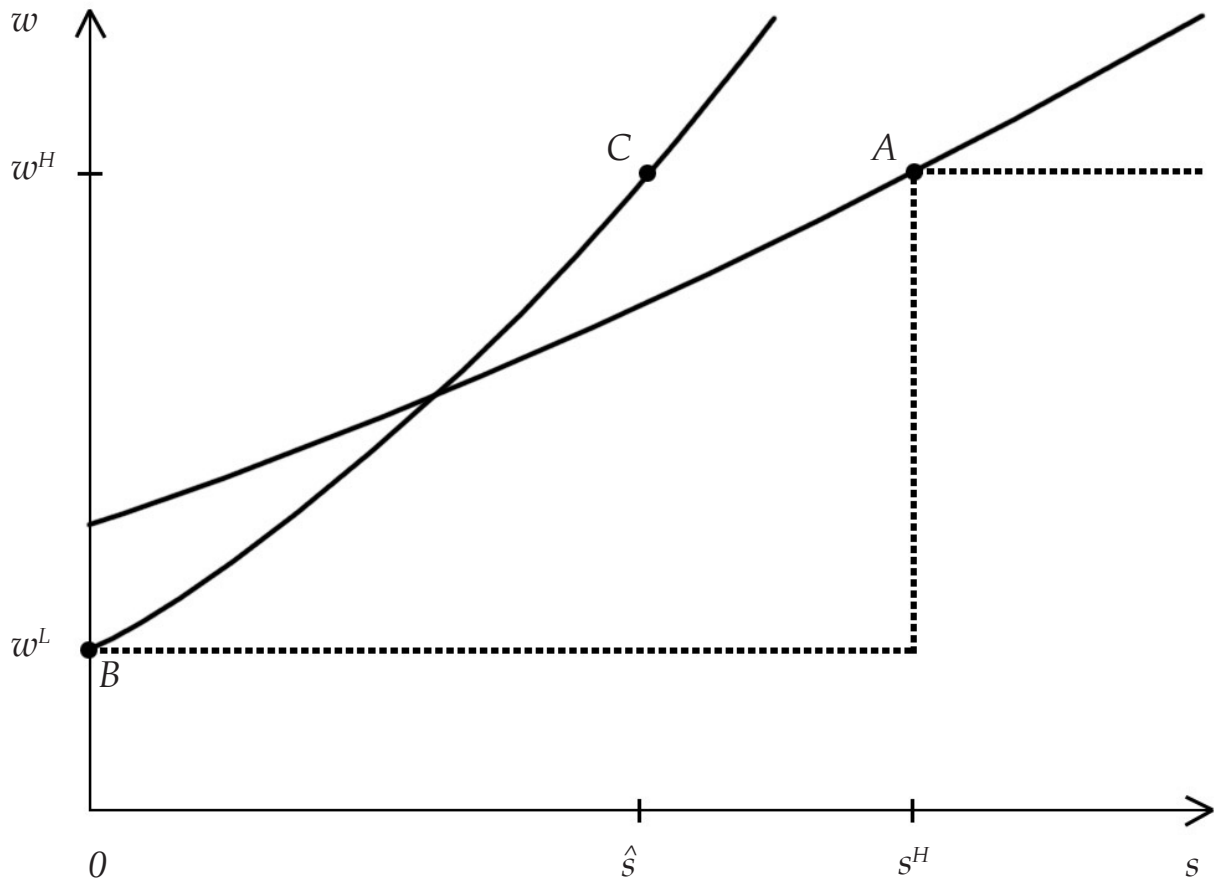


Figure 1.

Indifference curve for low-productivity job applicants (steep).
 Indifference curve for high-productivity job applicants (flat).

which are drawn to capture the assumption that education is less costly for high-productivity individuals. The flatter curve through point A thus represents those education-wage combinations (s, w) that high-productivity individuals find equally good as their expected education-wage pair (s^H, w^H) . All points northwest of this curve are regarded as better than this alternative, while all points to the southeast are regarded as worse. Likewise, the steeper curve through B indicates education-wage combinations that low-productivity individuals find equally good as the minimum education $s^L = 0$ and wage w^L .⁶

With these preferences, high-productivity individuals choose educational level s^H , neither more nor less, and receive the higher wage, as alternative B gives them a worse outcome than alternative A . Conversely, low-productivity individuals optimally choose the minimum educational level at B , since they are worse off with alternative A – the higher wage does not compensate for their high cost of education. Employers' expectations that workers with different productivity choose different educational levels are indeed self-fulfilling in this signaling equilibrium. Instead of a market failure, where high-productivity individuals remain outside of the market (e.g., by moving away or setting up their own business), these workers participate in the labor market and acquire a costly education solely to distinguish themselves from low-productivity job applicants.

Absent further conditions, there is a whole continuum of educational levels s^H with corresponding signaling equilibria. However, incentive compatibility requires that the expected level of education not be so high that high-productivity individuals prefer to refrain from education, or so low that low-productivity applicants prefer to educate themselves up to that level. Geometrically, these conditions imply that point B lies below the indifference curve of high-productivity individuals through any equilibrium point corresponding to A , and points like A lie below the indifference curve of low-productivity individuals through point B .

Spence (1973) indicates that a certain signaling equilibrium is the socially most efficient. In this equilibrium, high-productivity individuals opt for (and are expected to do so by the employers) the minimum education to distinguish themselves from those with low productivity. In other words, high-productivity workers choose the combination given by point C in *Figure 1*. Low-productivity workers are then indifferent between the education-wage combination (\hat{s}, w^H) at point C and the combination $(0, w^L)$ at their chosen point B . High-productivity individuals, conversely, prefer point C to B . Riley (1975) showed that this is the only signaling equilibrium

⁶The crucial assumption that more productive applicants find it sufficiently less costly to acquire an education – the flatter indifference curve in *Figure 1* – is closely related to Mirrlees' (1971) so-called single-crossing condition. A similar condition is found in numerous contexts in modern microeconomic theory and is often referred to as the Mirrlees-Spence condition.

which is robust to wage experimentation by employers. Spence's signalling model also spurred a flurry of game-theoretic research. In particular, various refinements of the Nash equilibrium concept have been developed to discriminate between the many signaling equilibria in Spence's model. Many of these refinements select the socially most efficient signaling equilibrium. An influential paper in this genre is Cho and Kreps (1987).

Spence (1973, 1974) also demonstrates the existence of other equilibria, e.g., one where no applicant acquires education. Assume that employers do not expect education to be a productivity signal, i.e., they expect all job applicants, regardless of education, to have the average productivity on the market: $\bar{w} = \lambda w^L + (1 - \lambda)w^H$. Employers then offer this wage to all job applicants, and their expectations are self-fulfilling, as it is optimal for all applicants to choose the minimum level of education $s^L = 0$. Spence also notes the possibility of equilibria where, say, high-productivity men are expected to acquire another level of education than equally productive women. In such an equilibrium, the returns to education differ between men and women, as do their investments in education.

Apart from his work on signaling, Spence has made distinguished contributions to the field of industrial organization. During the period 1975-1985, he was one of the pioneers in the wave of game-theory inspired work within the so-called new industrial organization theory. His most important studies in this area deal with monopolistic competition (1976) and market entry (1977). Spence's models of market equilibrium under monopolistic competition have also been influential in other fields, such as growth theory and international trade.

3. JOSEPH STIGLITZ

Stiglitz's classical article with Rothschild on adverse selection, "Equilibrium in Competitive Insurance Markets: An Essay on the Economics of Imperfect Information" (Rothschild and Stiglitz, 1976), is a natural complement to the analyses in Akerlof (1970) and Spence (1973, 1974).⁷ Rothschild and Stiglitz ask what uninformed agents can do to improve their outcome in a market with asymmetric information. More specifically, they consider an insurance market where companies do not have information on individual customers' risk situation. The (uninformed) companies offer their (informed) customers different combinations of premiums and deductibles and, under certain conditions, customers choose the policy preferred by the companies. Such screening through self-selection is closely related to Vickrey (1945) and Mirrlees' (1971) analyses of optimal income taxation, where a tax authority (unaware

⁷Salop and Salop (1976) similarly analyze how firms can use self-selection when employing workers with private information about their propensity to quit.

of private productivities and preferences) gives wage earners incentives to choose the “right” amount of work effort.⁸

Rothschild and Stiglitz’s model may be illustrated by means of a simple example. Assume that all individuals on an insurance market are identical, except for the probability of injury of a given magnitude. Initially, all individuals have the same income y . A high-risk individual incurs a loss of income $d < y$ with probability p^H and a low-risk individual suffers the same loss of income with the lower probability p^L , with $0 < p^L < p^H < 1$. In analogy with Akerlof’s buyer and Spence’s employer, who do not know the sellers’ quality or the job applicants’ productivity, the insurance companies cannot observe the individual policyholders’ risk. From the perspective of an insurance company, policyholders with a high probability p^H of injury are of “low quality”, while policyholders with a low probability p^L are of “high quality”. In analogy with the previous examples, there is perfect competition in the insurance market.⁹ Insurance companies are risk neutral (cf. the earlier implicit assumption of constant returns to scale), i.e., they maximize their expected profit. An insurance contract (a, b) specifies a premium a and an amount of compensation b in the case of income loss d . (The deductible is thus the difference $d - b$.)

Rothschild and Stiglitz establish that equilibria may be divided into two main types: pooling and separating. In a pooling equilibrium, all individuals buy the same insurance, while in a separating equilibrium they purchase different contracts. Rothschild and Stiglitz show that their model has no pooling equilibrium. The reason is that in such an equilibrium an insurance company could profitably cream-skim the market by instead offering a contract that is better for low-risk individuals but worse for high-risk individuals. Whereas in Akerlof’s model the price became too low for high-quality sellers, here the equilibrium premium would be too high for low-risk individuals. The only possible equilibrium is a unique separating equilibrium, where two distinct insurance contracts are sold in the market. One contract (a^H, b^H) is purchased by all high-risk individuals, the other (a^L, b^L) by all low-risk individuals. The first contract provides full coverage at a relatively high premium: $a^H > a^L$ and $b^H = d$, while the second combines the lower premium with only partial coverage: $b^L < d$. Consequently, each customer chooses between one contract without any deductible, and another contract with a lower premium and a deductible. In equilibrium, the deductible barely scares away the high-risk individuals, who are tempted by the lower premium but choose the higher premium in order to avoid the deductible. This unique possible separating equilibrium corresponds to the socially most efficient

⁸Stiglitz (1975) actually used the word “screening”, but addressed what is today known as signaling. Stiglitz refers to Arrow (1973) and Spence (1973), while discussing and extending their ideas.

⁹Stiglitz (1977) provides an analysis of the monopoly case.

signaling equilibrium, point C of *Figure 1* in the simple illustration of Spence's model above.¹⁰ Rothschild and Stiglitz also identify conditions under which no (pure strategy) equilibrium exists.¹¹

The uniqueness of equilibrium is typical of screening models, as is the correspondence between the screening equilibrium and the socially most efficient signaling equilibrium. Rothschild and Stiglitz's article has been very influential. In particular, their classification of equilibria has become a paradigm; pooling and separating equilibria are now standard concepts in microeconomic theory in general and in information economics in particular.

Stiglitz has made many other contributions regarding markets with asymmetric information. He is probably the most cited researcher within the information economics literature – perhaps also within a wider domain of microeconomics. In his large production, often with coauthors, Stiglitz has time and again pointed out that economic models may be quite misleading if they disregard informational asymmetries. The message has been that in the perspective of asymmetric information, many markets take on a different guise, as do the conclusions regarding the appropriate forms of public-sector regulation. Several of his essays have become important stepping stones for further research.

Two papers coauthored by Stiglitz and Weiss (1981, 1983) analyze credit markets with asymmetric information.¹² Stiglitz and Weiss show that to reduce losses from bad loans, it may be optimal for banks to ration the volume of loans instead of raising the lending rate, as would be predicted by classical economic analysis. Since credit rationing is so common, these insights were important steps towards a more realistic theory of credit markets. They have had a substantial impact in the fields of corporate finance, monetary theory and macroeconomics.

Stiglitz's work with Grossman (Grossman and Stiglitz, 1980) analyzes the hypothesis of efficiency on financial markets. It introduces the so-called Grossman-Stiglitz paradox: if a market were informationally efficient – i.e., all relevant information is

¹⁰ Riley's (1975) robustness test, with respect to experimenting employers, led to the same equilibrium in Spence's model. In fact, Riley's idea is not wholly unlike that of Rothschild and Stiglitz (1976). However, Rothschild and Stiglitz made "... a more radical departure from Spence's analysis by proposing that the model should be viewed as a non-cooperative game between the consumers." (Riley 2001, p. 438).

¹¹The non-existence problem has spurred some theoretical research. Wilson (1977), for example, suggests a less stringent definition of equilibrium, based on the idea that unprofitable contracts can be withdrawn. This renders certain otherwise profitable deviations unprofitable and makes existence more likely.

¹²Stiglitz and Weiss also study moral hazard, a concept already used by Arrow (1963) to refer to situations where an economic agent cannot observe some relevant action of another agent after a contract has been signed.

reflected in market prices – no agent would have an incentive to acquire the information on which prices are based. But if everyone is uninformed, then it pays some agent to become informed. Thus, an informationally efficient equilibrium does not exist. This work has exerted considerable influence in financial economics.

Stiglitz has proposed an information-based explanation of involuntary unemployment. In a widely cited article, Shapiro and Stiglitz (1984) develop a labor-market model with so-called efficiency wages.¹³ By definition, an efficiency wage exceeds a worker's reservation wage (the wage level which makes him indifferent between remaining on the job or quitting) and thus gives workers incentives to perform well (more efficiently) to keep their jobs. In Shapiro and Stiglitz's model, an employer is assumed to carry out random surveys among his employees to observe their work effort. A worker caught shirking is fired and ends up with his reservation wage (by looking for another job or setting up his own business), a level lower than if he had refrained from shirking and instead kept his job at the prevailing wage. Optimal behavior of both employers and employees results in equilibrium unemployment. Shapiro and Stiglitz's model is an important ingredient in modern labor and macroeconomics.

Stiglitz is also one of the founders of modern development economics. He has shown that economic incentives under asymmetric information are not merely academic abstractions, but highly concrete phenomena with far-reaching explanatory value in the analysis of institutions and market conditions in developing economies. One of his first studies of informational asymmetries (Stiglitz, 1974a) deals with sharecropping, an ancient but still common form of contracting. As the term implies, the contract regulates how the harvest should be divided between a landowner and his tenants. The size of a harvest generally depends on external circumstances such as weather and on the tenants' work effort. Under the conventional assumption that absolute risk aversion is decreasing in wealth, the optimal outcome would be to let the richer party (here, the landowner) bear the entire risk. In practice, however, the harvest is divided up between the parties according to fixed shares, usually half each. Stiglitz (1974a) and Akerlof (1976) both attempted to explain this relation, in terms of asymmetric information between the two parties. Since the landowner usually cannot observe tenants' work effort, an optimal contract strikes a balance between risk sharing and incentives, letting the tenants assume some share of the risk.

In addition to his work on the economics of information, Stiglitz has made significant contributions to public economics, especially the theory of optimal taxation (see e.g., Stiglitz and Dasgupta, 1971), industrial organization (see e.g., Dixit and Stiglitz, 1977), and the economics of natural resources (see e.g., Stiglitz 1974b and Dasgupta and Stiglitz, 1980).

¹³Concurrent research with similar ideas is reported in Bowles and Boyer (1988).

4. APPLICATIONS AND EVIDENCE

Akerlof, Spence and Stiglitz's analyses of markets and information asymmetries are fundamental to modern microeconomic theory. This research has furthered our understanding of phenomena in real markets which could not be fully captured by traditional neoclassical theory. Moreover, their models have been used to explain the emergence of many social institutions that counteract the negative effects of informational asymmetries. The range of application is remarkable: from financial markets, through industrial organization, all the way to issues in economic development. This section offers a selection of such applications from recent research and a brief discussion of some empirical tests of the models.

In financial economics e.g., Myers and Majluf (1984) have shown how shareholders can become victims of adverse selection among firms. In a new sector (such as today's IT) most firms may appear identical in the eyes of an uninformed investor, while some insiders may have better information about the future profitability of such firms. Firms with less than average profitability will therefore be overvalued by the stock market where, of course, uninitiated investors also trade. Such firms will therefore prefer to finance new projects by issuing new shares (as opposed to debt). Firms with higher than average profitability, on the other hand, will be undervalued and find it costly to expand by share issue. Under asymmetric information, the "low-quality" firms (with low future profitability) thus tend to grow more rapidly than "high-quality" firms, implying that the market will gradually be dominated by "lemons". When uninitiated investors ultimately discover this, share prices fall (the IT bubble bursts).

Another puzzle in financial economics is why some firms choose to distribute dividends to their shareholders, even if dividends are more heavily taxed (due to double taxation) than capital gains, as is the case in many countries. A cheaper alternative would be to retain the profits within the firm and favor shareholders by way of capital gains through a higher share price. John and Williams (1985) show that, under asymmetric information, dividends can act as a credible signal for a "high-profitability" firm on the stock market. Firms with positive insider information pay dividends to their shareholders, but this signal is too costly for firms with inferior insider information. The stock market thus interprets costly dividends as a credible signal for favorable prospects and therefore pays a high price for the stock. Under certain conditions, the share price rises enough to compensate shareholders for the extra tax they have to pay on dividends – a separating equilibrium is achieved.

In the sphere of industrial organization, numerous applications have shown how consumers may interpret price setting and advertising as signals for good quality. As in Spence's (1973, 1974) model of a labor market with high- and low-productivity

workers, equilibria can arise when it is profitable for firms with high-quality products to engage in costly advertising, whereas firms which produce low-quality goods refrain (see e.g., Nelson, 1974 and Milgrom and Roberts, 1986). Tirole (1988) provides an extensive overview of other applications of information economics in the field of industrial organization.

In labor economics, Waldman (1984) examines a situation where firms competing for labor use the job assignment of a competitor's employee as a signal his ability. Since an employer does not want to signal the true capacity of a good employee to potential competitors, employees might not necessarily be assigned tasks which maximize their contribution to the firm's profits. Such allocation of labor within firms might be optimal for an individual firm in a labor-competitive situation, but results in social inefficiency,

Bernhardt (1995) develops these arguments into an analysis of promotions, explaining why low-education employees promoted to high positions are usually extraordinarily capable. An employer who wants to hide his private information about employees from a competing employer has an incentive not to promote competent workers. For a promotion to be profitable, a low-educated worker therefore has to be sufficiently capable to compensate for the higher wage the firm is forced to pay to retain a worker whose competence is revealed to potential competitors. Similar mechanisms can also explain wage discrimination. Milgrom and Oster (1987) point out that such discrimination leads to social inefficiency when workers are assigned to the wrong jobs or are not given sufficient incentives to become better educated.

Riley (1979) makes an early attempt to empirically test Spence's signaling model. Riley's idea is that signaling should be most important in those sectors of the economy where worker productivity is difficult to measure. In such sectors, wages and education are thus expected to be strongly correlated at the outset of a worker's career, whereas the correlation should be weaker in sectors where productivity is more easily observed. Over time, as firms learn more about the productivity of their employees, the correlation between wages and education should become weaker, particularly in sectors where productivity is hard to measure. Riley was able to confirm these effects empirically. More recent tests of Spence's signaling model were carried out by Lang and Kropp (1986) and Bedard (2001). Both studies show that data on high-school enrollments and dropout rates are consistent with a signaling model and inconsistent with a pure human-capital model.

In their empirical analysis of firing on a labor market with asymmetric information, Gibbons and Katz (1991) test the relevance of adverse selection and signaling. If firms can freely decide which employees should be fired, other agents on the labor market will conclude that the ability of fired workers is below average (they are "lemons"). Workers who are alike in all other (measurable) respects, but who had to leave their

jobs because the firm closed down, should thus find it easier to get a new job and receive a higher wage. Based on a large sample of redundant workers, Gibbons and Katz find empirical support for these predictions.

Farber and Gibbons (1996) developed Spence's signaling model by allowing employers to obtain information on worker productivity by observing their careers. The model predicts that the wage effect of education is independent of the length of time a worker has been on the labor market, whereas the wage effect of constant, unobservable characteristics, which are positively correlated with worker ability, increases with the time a worker has been employed. Both predictions are consistent with data regarding young people on the US labor market.

Acemoglu and Pischke (1998) show that asymmetric information about worker ability can explain on-the-job training in firms. The mechanism resembles that in Waldman (1984) and Gibbons and Katz (1991). Informational asymmetries concerning a trained worker's productivity generate a monopsony (a buyer monopoly) on the local labor market, implying that the firm can successively pay for the training by a wage which falls short of the competitive wage. The predictions are empirically supported when confronted with data from the German apprentice system.

Other attempts to test for the predicted effects of asymmetric information have produced ambiguous results. One difficulty with such tests is to distinguish, in practice, between adverse selection and moral hazard; another is that screening and signaling partially eliminate the effects of informational asymmetries.¹⁴

In recent years, many insights from the economics of information have been incorporated into development economics. It is perhaps not so surprising that models suggested by Akerlof and Stiglitz have had a large influence in this field, as their early studies were largely inspired by issues in development economics. Prime examples are Akerlof's lemons model and Stiglitz's sharecropping model. Extensions of the latter e.g., have been used to explain institutional relationships between landowners and tenants, such as why landowners often grant credit to tenants (it has positive incentive effects on work effort). Arguments based on asymmetric information have also been used to clarify the dichotomy between modern and traditional sectors in developing economies. Basu (1997) is an example of a modern advanced textbook in development economics that builds heavily on the economics of information.

¹⁴A direct test carried out by Bond (1982) on data from a market for second-hand small trucks does not lend support to the asymmetric information hypothesis. Dahlby (1983, 1992) finds some support for adverse selection using aggregate data on Canadian car insurance. In a study of data from a car-insurance company, Puetz and Snow (1994) find support for both adverse selection and signaling. Chiappori and Salanié (2000) examine whether individuals with a higher risk of having an accident systematically choose car insurance with better coverage. They are unable to find statistical support for such a correlation.

5. SUGGESTED READING

The laureates' own original works remain highly recommended reading: see e.g., Akerlof (1970, 1976), Spence (1973, 1974), Rothschild and Stiglitz (1976), Stiglitz and Weiss (1981) and Shapiro and Stiglitz (1984). Riley (2001) gives a detailed survey of economic analyses of markets with asymmetric information. Gibbons (1992) offers an accessible introduction to game-theoretic modeling of asymmetric information. A more advanced introduction to adverse selection, signaling and screening can be found in Chapter 13 of Mas-Colell, Whinston and Green (1995).

REFERENCES

- [1] Acemoglu D. and S. Pischke (1998): “Why do Firms Train? Theory and Evidence”, *Quarterly Journal of Economics* 113, 79-119.
- [2] Akerlof G. (1970): “The Market for Lemons: Quality Uncertainty and the Market Mechanism”, *Quarterly Journal of Economics* 84, 485-500.
- [3] Akerlof G. (1976): “The Economics of Caste and of the Rat Race and other Woeful Tales”, *Quarterly Journal of Economics* 90, 599-617.
- [4] Akerlof G. (1980): “A Theory of Social Customs of which Unemployment May be One Consequence”, *Quarterly Journal of Economics* 94, 749-775.
- [5] Akerlof G. (1982): “Labor Contracts as Partial Gift Exchange”, *Quarterly Journal of Economics* 97, 543-569.
- [6] Akerlof G. and J. Yellen (1990): “The Fair Wage Hypothesis and Unemployment”, *Quarterly Journal of Economics* 105, 255-283.
- [7] Arrow K. (1963): “Uncertainty and the Welfare Economics of Medical Care”, *American Economic Review* 53, 941-973.
- [8] Arrow K. (1972): “The Value of and Demand for Information”, in McGuire, C. and R. Radner (eds.), *Decision and Organization*, North-Holland (London).
- [9] Arrow K. (1973): “Higher Education as a Filter”, *Journal of Public Economics* 2, 193-216.
- [10] Banerjee A. and A. Newman (1998): “Information, the Dual Economy, and Development”, *Review of Economic Studies* 65, 631-653.
- [11] Basu K. (1997): *Analytical Development Economics*, MIT Press (Cambridge, MA).
- [12] Bedard K. (2001): “Human Capital versus Signaling Models: University Access and High School Dropouts”, *Journal of Political Economy* 109, 749-775.
- [13] Berg I. (1970): *Education and Jobs: The Great Training Robbery*, Praeger (New York, NY).
- [14] Bernhardt D. (1995): “Strategic Promotion and Compensation”, *Review of Economic Studies* 62, 315-339.

- [15] Bewley T. (1999): *Why Wages Don't Fall During a Recession*, Harvard University Press (Cambridge, MA).
- [16] Bond E. (1982): "A Direct Test of the Lemons Model: The Market for Used Pickup Trucks", *American Economic Review* 72, 836-840.
- [17] Bowles S. and R. Boyer (1988): "Labor Discipline and Aggregate Demand", *American Economic Review* 78, 395-400.
- [18] Braverman A. and J. Stiglitz (1982): "Sharecropping and the Interlinking of Labor Markets", *American Economic Review* 72, 695-715.
- [19] Cho I.-K. and D. Kreps (1987): "Signaling Games and Stable Equilibria", *Quarterly Journal of Economics* 102, 179-221.
- [20] Chiappori P. and B. Salanié (2000): "Testing for Asymmetric Information in Insurance Markets", *Journal of Political Economy* 107, 56-78.
- [21] Dahlby B. (1983): "Adverse Selection and Statistical Discrimination: An Analysis of Canadian Automobile Insurance", *Journal of Public Economics* 20, 121-130.
- [22] Dahlby B. (1992): "Testing for Asymmetric Information in Canadian Automobile Insurance", in G. Dionne (ed.) *Contributions to Insurance Economics*, Kluwer (Boston).
- [23] Dasgupta P. and J. Stiglitz (1980): "Uncertainty, Industrial Structure, and the Speed of R&D", *Bell Journal of Economics* 11, 1-28.
- [24] Dixit A. and J. Stiglitz (1977): "Monopolistic Competition and Optimal Product Diversity", *American Economic Review* 67, 297-308.
- [25] Farber H. and R. Gibbons (1996): "Learning and Wage Dynamics", *Quarterly Journal of Economics* 111, 1007-1047.
- [26] Fehr E. och K. Schmidt (1999): "A Theory of Fairness, Competition and Cooperation", *Quarterly Journal of Economics* 114, 817-868.
- [27] Fehr E. and K. Schmidt (2000): "Theories of Fairness and Reciprocity: Evidence and Economic Applications", forthcoming in M. Dewatripont et al. (eds.), *Advances in Economic Theory, Eighth World Congress of the Econometric Society*, Cambridge University Press (Cambridge, UK).

- [28] Gibbons R. (1992): *A Primer in Game Theory*, Harvester-Wheatsheat, (New York, NY).
- [29] Gibbons R. and L. Katz (1991): “Layoffs and Lemons”, *Journal of Labor Economics* 9, 351-380.
- [30] Grossman S. and J. Stiglitz (1980): “On the Impossibility of Informationally Efficient Markets”, *American Economic Review* 70, 393-408.
- [31] John K. and J. Williams (1985): “Dividends, Dilution and Taxes: A Signalling Equilibrium”, *Journal of Finance* 40, 1053-69.
- [32] Lang K. and D. Kropp (1986), “Human Capital versus Sorting: The Effects of Compulsory Attendance Laws”, *Quarterly Journal of Economics* 101, 609-624.
- [33] Marschak J. (1959): “Remarks on the Economics of Information”, *Contributions to Scientific Research in Management*, Western Data Processing Center, University of California, Los Angeles, 79-98.
- [34] Mas-Colell A., M. Whinston and J. Green (1995): *Microeconomic Theory*, Oxford University Press (Oxford).
- [35] Milgrom P. and J. Roberts (1986): “Price and Advertising Signals of Product Quality”, *Journal of Political Economy* 94, 795-81.
- [36] Milgrom P. and S. Oster (1987): “Job Discrimination, Market Forces, and the Invisibility Hypothesis”, *Quarterly Journal of Economics* 102, 453-476.
- [37] Mirrlees J. (1971): “An Exploration in the Theory of Optimum Income Taxation”, *Review of Economic Studies* 38, 175-208.
- [38] Myers S. and N. Majluf (1984): “Corporate Financing and Investment Decisions when Firms Have Information that Investors Do Not Have”, *Journal of Financial Economics* 13, 187-221.
- [39] Nelson P. (1974): “Advertising as Information”, *Journal of Political Economy* 82, 729-54.
- [40] Puetz R. and A. Snow (1994): “Evidence on Adverse Selection: Equilibrium Signalling and Cross-Subsidization in the Insurance Market”, *Journal of Political Economy* 102, 236-257.

- [41] Riley J. (1975): “Competitive Signalling”, *Journal of Economic Theory* 10, 174-186.
- [42] Riley J. (1979): “Testing the Educational Screening Hypothesis”, *Journal of Political Economy* 87, 227-52.
- [43] Riley J. (2001): “Silver Signals: Twenty-Five Years of Screening and Signaling”, *Journal of Economic Literature* 39, 432-478.
- [44] Rothschild M. and J. Stiglitz (1976): “Equilibrium in Competitive Insurance Markets: An Essay on the Economics of Imperfect Information”, *Quarterly Journal of Economics* 95, 629-649.
- [45] Shapiro C. and J. Stiglitz (1984): “Equilibrium Unemployment as a Worker Discipline Device”, *American Economic Review* 74, 433-444.
- [46] Spence M. (1973): “Job Market Signalling”, *Quarterly Journal of Economics* 87, 355-374.
- [47] Spence M. (1974): *Market Signaling*, Harvard University Press (Cambridge, MA).
- [48] Spence M. (1976): “Product Selection, Fixed Costs and Monopolistic Competition”, *Review of Economic Studies* 43, 217-235.
- [49] Spence M. (1977): “Entry, Capacity, Investment and Oligopolistic Pricing”, *Bell Journal of Economics* 8, 534-544.
- [50] Stiglitz J. and P. Dasgupta (1971): “Differential Taxation, Public Goods and Economic Efficiency”, *Review of Economic Studies* 38, 151-174.
- [51] Stiglitz J. (1974a): “Incentives and Risk Sharing in Sharecropping”, *Review of Economic Studies* 41, 219-255.
- [52] Stiglitz J. (1974b): “Growth with Exhaustible Natural Resources: Efficient and Optimal Growth Paths”, *Review of Economic Studies* 41, 123-38.
- [53] Stiglitz J. (1975): “The Theory of ‘Screening,’ Education, and the Distribution of Income”, *American Economic Review* 65, 283-300.
- [54] Stiglitz J. (1977): “Monopoly, Non-Linear Pricing, and Imperfect Information: The Insurance Market”, *Review of Economic Studies* 44, 407-430.

- [55] Stiglitz J. and A. Weiss (1981): “Credit Rationing in Markets with Imperfect Information”, *American Economic Review* 71, 393-410.
- [56] Stiglitz J. and A. Weiss (1983): “Incentive Effects of Terminations: Applications to the Credit and Labor Markets”, *American Economic Review* 73, 912-927.
- [57] Tirole J. (1988): *The Theory of Industrial Organization*, MIT. Press (Cambridge, MA).
- [58] Vickrey W. (1945): “Measuring Marginal Utility by Reactions to Risk”, *Econometrica* 13, 319-333.
- [59] Waldman M. (1984): “Job Assignments, Signalling, and Efficiency”, *Rand Journal of Economics* 15, 255-267.
- [60] Wilson C. (1977): “A Model of Insurance Markets with Incomplete Information”, *Journal of Economic Theory* 16, 167-207.