IMPERFECT INFORMATION, LEGAL INSTITUTIONS, AND EXTERNALITIES

by

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Externalities have presented a difficulty in the attainment of Pareto optimal competitive equilibria in decentralized market economies. An externality can be said to exist whenever technological interdependencies between economic agents give rise to a divergence between social marginal cost and private marginal cost. The problem is that we have not thoroughly explored the question of why externalities persist. That is, why are externalities not internalized optimally in a market system? Why do markets fail? This thesis approaches these questions by examining the sources of market failure.

One source of market failure, transaction costs, is the focus of the thesis. The assumption that transaction costs are zero is relaxed. One particular type of transaction cost, imperfect technological information, is examined to see if the inclusion of this transaction cost in an otherwise competitive model can explain the persistence of specific classes of externalities. The externalities considered are private external diseconomies, i.e., interdependencies between agents that affect individuals separately. I do not consider externalities that have public good attributes.

We cannot fully discuss transaction costs without considering the effect of the institutions existing in an economy on these costs. This
thesis examines the relationship between one institution, the legal system, and imperfect information. The legal system comprises the set of individual rights, common and statutory laws, court system, and legal services markets which exist in a decentralized economy.

The thesis entails a theoretical examination of the persistence of private external diseconomies, given imperfect information. First, a taxonomy of legal rights is formulated. The importance of rights is established by showing that the assignment of rights influences resource allocation by affecting the equilibrium point attained given any type of externality (private or public) and zero transaction costs. A geometric bargaining model provides a counter-example to the "Coase theorem". But this model is too general to deal with specific externality and imperfect information cases.

Imperfect information in the context of externalities is defined explicitly and models employed to show that under certain information/externality cases, private markets either may not arise to allocate resources, or, if markets do exist, they may operate inefficiently. The markets examined are private insurance markets as they are one type of institution economic theory predicts would arise to internalize externalities in the case of imperfect information. It is found that insurance, as a market allocation mechanism, may not internalize certain types of externalities when information is imperfect.

The legal system is then examined in greater detail as an example of a nonmarket allocation mechanism. In particular, formal models are
used to investigate the effect of specific liability laws and due care standards on the attainment of Pareto optimal resource allocation, given private externalities and imperfect information. It is found that legal liability rules do not in general lead to optimal equilibria. In certain cases however, liability laws may improve social welfare by providing incentives for the parties involved in the externality to alter their behavior responsible for the externality.

In contrasting private insurance markets and legal rules with respect to the information each requires to operate and the equilibria attainable (if they exist), it is found that legal rules may be superior to private insurance markets. This result occurs because legal rules require less precise information than do insurance markets and may also be able to affect the behavior of all parties involved in the externality. Insurance generally covers only the parties damaged by the externality. In summary, this thesis provides a theoretical rationale for one type of market failure due to externalities and points out a nonmarket method of improving social welfare when externalities exist.
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I. INTRODUCTION

It is generally believed that externalities inhibit the attainment of an optimal allocation of resources given the assumptions of the perfectly competitive model. That this conclusion is accepted unequivocally by most economists is surprising, because there is no clear definition of what an externality is and why it exists when all perfect competition assumptions are met. Terms like market failure, non-appropriability, public goods and bads, spillovers, etc. pervade the literature. These terms attempt to convey the notion that externalities are things or activities that are excluded in the operation of the competitive price system. The traditional literature does not deal with the question of why externalities are excluded from competitive markets. The treatment of externalities in economic theory has ignored what I consider the fundamental question: why do we observe externalities? Instead, traditional externality considerations concentrate on policy issues: what actions can be taken to internalize externalities. There is a surfeit of articles dealing with the efficiency and optimality of policies to internalize externalities: taxes and subsidies, merger, regulations, and quotas. Emphasis on the cure is premature when we do not know the cause of the problem.

This thesis attempts to provide a theoretical rationale for the existence and persistence of a specific type of externality; a private, inter-personal or inter-firm external diseconomy. It is not possible to examine all types of externalities, so I shall therefore concentrate on particular examples. Before defining the cases I shall be concerned
with, I would like to examine a general definition of externality, point out some of its weaknesses, then introduce what I feel is a major cause of the persistence of specific types of externalities, namely, transaction costs.

A prevalent definition in the literature suggests that an externality exists when the utility of an individual or a firm's profit is dependent upon activities generated by another individual or firm. The affected agent is assumed to be unable to control the activities. This definition is due to a number of people, including Meade (1952) and Buchanan and Stubblebine (1962). It has been utilized in most of the externality literature with varying degrees of mathematical rigour. The "activities", never clearly defined, are assumed to be incompletely priced in competitive markets or not priced at all. Activity is a general term that is interpreted according to the case at hand. For example, an activity can entail the use of a factor of production (land, water, air), or be derived from a good (neighbour's flower garden) or bad (noise, stink). I prefer to view incompletely priced activities using Pigou's terminology (1932). Externalities will arise when technological interdependencies are combined with a divergence between private marginal costs (or products) and social marginal costs (or products). Some component of the externality may thus be priced, but the price is not necessarily equivalent to the social marginal value of the activity.

The important aspect of the definition is the assertion that externalities are unpriced or insufficiently priced. Herein lies one of the shortcomings of the definition. The activity is assumed to be unpriced.
Therefore, markets for the exchange of the goods or factors that generate externalities do not exist or operate imperfectly by assumption. The term market failure may be used, following Bator (1958) to describe this situation, i.e., the non-existence or inefficient operation of certain markets in the competitive framework. The problem with the traditional externality literature is that it gives insufficient explanation for the inefficiency or non-existence of markets where there are externalities. We observe that certain markets do not exist or work imperfectly. Methodologically, should the non-existence or imperfection of markets be an assumption or a hypothesis in a model? I would argue that market failure should be derived from a set of initial conditions, such as assumptions about the behavior of economic agents, the institutions affecting economic behavior, technological relationships, and so on. The traditional literature generally ignores these initial conditions and assumptions, treats market failure as an (or the) assumption, then proceeds to analyze methods of pricing externalities optimally.

I think that the fundamental explanation for the presence of externalities is that less than a full set of markets operate in an economy. If there are n goods in the economy, then in theory (n - 1) markets will exist. What I ask is why certain markets, those involving

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1 Market failure was analyzed by Bator (1958), but never in a rigorous fashion. Bator's classification is too broad and not useful for my analysis. My interest in the market failure approach emanates from a stimulating paper by Arrow (1969).

2 Externalities are not the only result of an economy that operates less than a full set of markets. Other examples are the lack of futures markets and certain markets for risk-bearing.
externalities, do not exist. Consider an economy with sets of markets for all possible present and future goods. All goods can be exchanged through markets in this economy. For example, individuals would pay for the right to view each other's gardens, to dump garbage in the river, to blow smoke in people's faces, etc. Perhaps the first thing one would notice in such an economy is that substantial amounts of resources are being devoted to the operation of markets. Processes of gathering and assimilating information, monitoring agents' actions, and enforcing the rules under which markets operate would be extensive, and one might guess, very costly. One might ask if the use of the resources to operate markets is warranted.

In the real world, we do not observe at any point in time, all possible markets in operation. One reason why a private, unregulated market may not exist is that there exist transaction costs of operating the market.\(^1\) Transaction costs are a function of the institutional characteristics of an economy. As Arrow (1969, p. 48) has noted, "market failure in general and externalities in particular are relative to the mode of economic organization". Market failure is not a technological phenomenon, nor is it absolute. Technology will determine the

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\(^1\) Of course, markets may fail for other reasons, namely when goods are consumed publically. Many externalities have public good attributes. Smoke pollution, for example, will be a public bad because once the pollution is generated, many individuals consume it simultaneously. There is a vast amount of literature on the relationship between externalities and public goods. I do not wish to enter this taxonomic debate. My thesis will concentrate on private externalities to avoid the added complexities introduced by public goods. In addition, I will examine only external diseconomies as they are empirically more significant than external economies and present a more complex (and hence, interesting) set of problems.
method of producing goods, but it does not determine which goods are marketed. It could be argued that there exist technological relationships between externalities and goods or factors that lead to joint consumption or production. In a dynamic economy, the degree of jointness will vary with the state of the technology. The non-marketing of certain goods jointly produced or consumed is not a function of technology, but rather due to transaction costs.

Transaction cost is a general term and we must examine the sources of these costs. Transaction costs can be defined as the costs in terms of real resources consumed of exchanging title to ownership of a commodity (goods or factors) (Demsetz, 1968, p. 35). Other possible synonymous terms include contracting costs and marketing costs. What gives rise to these costs? In general cases of externality, there are two major sources of transaction costs. First, excluding non-buyers from consuming certain commodities may be technologically impossible or require a large expenditure of resources. This cost is known as non-appropriability.\(^1\) An example is pollution abatement. Dirty air is shared by a large number of individuals who have no ability individually to alter the amount and quality of the air they consume. The costs of monitoring agents' behavior could also be included in this category. I shall not deal with externalities that persist because of non-appropriability, but focus on another type of transaction cost.

I shall concentrate on transaction costs that arise from uncertainty and imperfect information. This category is somewhat general and can

\(^1\) Non-appropriability is also a necessary condition for the existence of public goods.
include for example, the costs of negotiating a contract, and the costs of obtaining information about the prices or quality of a good, individuals' preference orderings, or technological relationships between jointly produced or consumed goods. We could also consider incentive problems; what is necessary to induce agents to reveal information? Information, or the lack of it, is an extremely important source of transaction costs. There is some debate whether transaction costs are a function of information or the reverse. I prefer, following Arrow (1969), to consider transaction cost the general category, with information problems a contributory source of the costs. When dealing with models incorporating transaction costs, one has to clearly specify the information structure for all economic agents involved.

We must now ask how institutions can influence transaction costs. This question cannot be answered without an examination of legal rules and property rights. I shall therefore focus my attention on legal institutions, i.e., the set of common and statutory laws and the legal system which enacts and enforces these laws in a decentralized economy. Rights have an important effect on information costs. If rights are non-existent or non-exclusive for a particular resource or good, a common property situation exists and the market for that resource or good may fail. Transferability of rights will also affect costs. If a right for the exchange of a good is non-transferable, the market for that used good does not exist. Where transferability rights exist but are costly, only certain subsets of markets may operate. Transferability and exclusivity in turn depend on legal institutions which have the task
of delineating and enforcing rights, for example, the determination of liability laws. Operation of legal institutions is not costless, and these transaction costs will affect the operation of markets. Demsetz (1966, 1969) and others (of the "Chicago school") have argued that markets for externalities will not exist when the transaction costs of operating these markets are too high. This assertion is invalid without an examination of the effects of legal rules and institutions on transaction costs. Costs that are "too high" under one set of institutions may be low enough to make the market work with other sets of institutions or rights.

A question arises at this point as to whether transaction costs can be reduced by government control of the exchange of goods. That is, given that there are costs of operating markets privately, can central control by government efficiently allocate resources with less cost than the market? To show that government control is less costly requires, for example, that government has more information, can police rights with less cost, or, because of its size, can pool risks and operate insurance markets. It cannot be assumed that centralized government control of resource allocation is superior to decentralized private market activity.

The assumption of competitive equilibria in all possible markets presents some difficulties in my analysis. It may not be a valid

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1 Any verification of the superiority of government control over private market operation is hampered by the lack of an economic theory of government. No clearly defined objective function exists for either consumption or production activities of governments. Without some empirical evidence, we are left only with assumptions about the government's ability to minimize transaction costs.
assumption when transaction costs exist. The traditional externality
literature argues that given any type of externality, competitive equi-
libria exist, but the resulting equilibria may not be Pareto optimal.
If transaction costs are zero, what Negishi (1972) and others have im-
plicitly shown is that externalities will not persist in competitive
markets. Markets would be costlessly set up or emerge to internalize all
externalities, and we would observe Pareto optimal resource allocations.
Systems of taxes and subsidies, bargaining, merger, and so on are equiva-
lent to implementing markets in these traditional externality models. But,
why would these policies even be necessary in a world of costless trans-
actions? Without some form of transaction cost, for example, imperfect
information, legal restrictions on liability claims, government interven-
tion in markets, we would not expect to observe externalities in competitive
markets. The assumption of competitive equilibria thus precludes exter-
nalities and the assumption of transaction costs may preclude perfect
competition. When one considers certain transaction costs explicitly
(for example, imperfect information), competitive equilibria may be
incompatible with efficient and optimal equilibria. In addition,

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1 This conclusion does not hold if externalities give rise to noncon-
vexities in production or consumption possibility sets. See Arrow
(1969) and Starrett (1972) for a discussion of externalities and
nonconvexity. See Negishi (1972) for a proof of the conclusion in a
general equilibrium model. Papers by Ledyard (1971) and Osana (1972)
have shown that under certain assumptions about the nature of exter-
nalities and information in the economy, the welfare theorems may hold.
Also see Camacho (1970). No one, to my knowledge, has explicitly examined
the welfare theorems under different transaction cost assumptions.

2 See Chapter III, part C of this thesis.
transaction costs may lead to nonconvexities which can prevent the attainment of competitive market equilibria.

Transaction costs may thus give rise to market failure due to externalities. The traditional externality literature has not considered transaction costs explicitly. Their corrective solutions imply the creation of markets, but the solutions tell us little about the feasibility and optimality of the resulting equilibria. The costs of operating these corrective policies and the types of transaction costs that give rise to market failure due to externalities are ignored. By examining the possible types of transaction costs that give rise to externalities, one adds both a more realistic dimension to the analysis of the problem and a more consistent theoretical framework for analysis. The traditional literature does not give a satisfactory explanation for the persistence of externalities. As Crocker (1973, p. 563) has noted

To assert that a result is efficient because it is the outcome that would occur with omnipresent markets after having initially made a set of assumptions inexorably leading to the conclusion that a market is the only form of economic cooperation that leads to efficient outcomes is not very enlightening. If markets are in fact costly, this sort of reasoning does not provide any obvious conclusions about the efficiency of markets or of any other institutions as modes of allocation and economic cooperation.

The approach to externalities outlined in this introduction gives rise to a number of interesting and, as yet, unanswered problems. One could develop partial and general equilibrium models of markets with transaction costs and externalities under a variety of assumptions about transaction costs and institutions. From these models, one could then
develop and evaluate alternative methods of internalizing externalities and apply the analysis to "real world" problems. This thesis concentrates on one particular aspect of the problem of externalities and transaction costs, the effects of imperfect information on market and nonmarket allocation mechanisms with externalities. I shall deal with private external diseconomies. I do not consider cases where externalities are public in nature. Examples of the type of externalities I shall examine include upstream-downstream pollution, defective products that injure individuals, and industrial pollutants that affect individual workers.

The thesis is structured as follows. Chapter II considers the role of legal institutions in the operation of competitive markets. A taxonomy of legal rights is formulated, and the impact of one type of these rights on resource allocation with traditional externalities is examined. Externalities are treated generally in this chapter, as I wish to point out the limitations of the traditional analysis and the need to choose specific externality cases for formal analysis. Chapter III defines externalities in the context of imperfect information as a specific transaction cost, and examines the feasibility of using private insurance markets to internalize externalities in a decentralized economy. As the results in Chapter III with regard to insurance markets are rather pessimistic, Chapter IV considers the use of the legal system as a nonmarket allocation mechanism, concentrating on the use of liability rules to internalize externalities. The general results and implications of the thesis are summarized in Chapter V.
II. THE ROLE OF LEGAL INSTITUTIONS IN THE OPERATION OF MARKETS

A. Introduction: A Taxonomy of Legal Rights

It has been asserted that the assignment of property rights and legal institutions in general have no effect on the allocation of resources and operation of markets (or exchange processes) in a competitive economy (e.g., Furubotn and Pejovich (1972), Coase (1960), Demsetz (1966, 1967)). The only way in which these institutions are assumed to influence economic decision-making is through their distributive effects. Rights are only supposed to affect the level and distribution of income and can thus be ignored in models concerned with allocative efficiency when all competitive assumptions are met.¹ If, however, this assertion is incorrect, and rights do affect resource allocation, then models which abstract from consideration of rights and other legal constraints may yield predictions that are invalid in certain cases. Two questions arise. First, is the assertion that rights do not affect resource allocation valid? Secondly, if alternative assignments of rights affect the relative prices of goods and/or factors, how and when should legal variables be introduced into economic models? It is my intention to show that legal institutions do affect resource allocation, and that it is necessary to include an explicit consideration of rights in any attempt to explain the existence and persistence of externalities.

¹ A disturbing consequence of the assertion that property rights do not affect competitive equilibria is that this assertion can be interpreted to imply the optimality of existing rights and used to justify the status quo.
Let me first note that the entire argument concerning the symmetry (or neutrality or invariance) of rights in the context of a full set of markets with zero transaction costs is of little relevance to the problem of externality. As noted in Chapter I, we cannot assume the existence of externalities in a world where all the assumptions of perfect competition are met. The presence of certain types of rights and liability rules suggests that the competitive assumption (or requirement) of universal markets (Arrow (1969)) may be violated. What is missing in most economists' discussion of legal institutions is a systematic definition and analysis of these institutions. The term "property right" is, for example, used by economists to mean a variety of things and is often not defined at all. It is neither appropriate nor meaningful to insert rights or laws into competitive models without specifying what rights are or how they relate to the necessary and sufficient conditions for the existence of perfectly competitive markets. Articles such as those by Furubotn and Pejovich (1972), Coase (1960), and Demsetz (1966) are subject to this criticism, and we must thus be suspicious of their assertions and "theorems". Before considering the effect of legal institutions on the generation of externalities, I find it necessary to discuss the possible roles of these institutions in the competitive model. This task will begin with a brief taxonomic discussion of legal institutions.

The following classification of legal institutions is not exhaustive. I am only considering the civil legal procedures (essentially the law of torts) that can affect the operation of markets and the existence of externalities. Becker (1968), Stigler (1970), and others have examined
the effects of criminal law on the production of crime and illegal activities. I do not wish to consider these topics, although it could be argued that criminal laws pertain to externality situations. My analysis simplifies many legal concepts and does not deal with the intricate and subtle nuances of the law. The intention is not to incorporate all aspects of legal systems into economic analysis, but rather to consider some general and abstract principles of law as they apply to the behavior of economic agents and the operation of markets.¹

Most laws act as constraints on economic agents' choice sets. Posner (1972, p. 393) defines a law as a "command backed by the coercive power of the state". Although it is conceivable that people derive utility (either positive or negative) from laws, I do not feel that the treatment of laws as arguments of utility functions will aid in an analysis of the existence of markets for goods. The derivation of demand functions for laws would not resolve the difficulties that externalities pose for decentralized economies. Although individuals do not demand laws in my analysis, they may require adjudication to obtain an assignment of rights. Adjudication in turn requires legal services, and individuals may thus demand legal services (a derived demand).² In my

¹ I also wish to ignore at this point, the difficult and prior problems of rationalizing the emergence of laws, legal institutions, and governments that enact these laws. See part A of Chapter IV for a brief discussion of some of the problems of determining rights. For the purposes of this chapter, I merely assume that the necessary legal institutions exist and rights are defined.

² In Chapter IV, I consider some possible effects of the legal services market on the determination of rights.
analysis, laws must therefore enter economic models as constraints on behavior and choice. The type and nature of the constraint depends upon the law under consideration and the economic assumptions defining agents' environments and behavior. Certain laws make sense only under specific assumptions about the state of the world.

I propose the following taxonomy. \(^1\) Laws as constraints can be partitioned into two categories: prior rights and contingent rights. Prior rights comprise those laws which govern the ex ante distribution and use of resources. They are necessary for the operation of an economic system. In an ideal world, analogous to the world depicted by Arrow and Debreu (1951, 1954, 1959), prior rights should satisfy four conditions. They must be comprehensive, exclusive, transferable, and enforceable, to allow for the possible efficient operation of markets. \(^2\) Comprehensiveness means that prior rights must be defined over all commodities. The definition of commodity becomes crucial in this context. To make any sense, rights must cover both the physical attributes of commodities and the services rendered by commodities as distinct entities. For example, labour services and the actual workers are separate commodities. Workers have the right to sell their services but

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\(^1\) This taxonomy is not exhaustive; clearly other classifications of laws and legal rules are possible.

\(^2\) The first three conditions are discussed by Posner (1972) in a different context, and are modified somewhat to fit my taxonomy. Also see Cheung (1970). Note that if prior rights do not satisfy the four conditions, markets may still exist, but may function inefficiently. In these cases, market failure may still exist.
not themselves. Firms may own (de facto) the right to emit pollution (a negative commodity service), but they do not actually own the physical commodity being polluted (air, water, etc.). The laws that affect comprehensiveness of prior rights could be called property laws and these laws give rise to property rights. This use of the term is more specific than the somewhat inexplicit definitions of property rights given in the traditional literature. One function of prior rights is thus the delimitation of initial endowments, that is, wealth, in the form of ownership of property: physical commodities and commodity services.

Prior rights must be exclusive. Two different agents (or sets of agents) cannot possess the same right to property at the same time. The inefficiencies resulting from the non-exclusive ownership of resources have been the subject of considerable study (common property resources). The third condition for prior rights is that they should be transferable. The law of contracts affects exchange of prior rights. Contract laws enable owners of property rights to make and set the conditions of exchange of the commodities under their control, i.e., they help to define markets and are a necessary condition for the existence of markets. Laws of contracts can impose constraints on the terms of exchange. In an ideal world where rights correspond to all commodities, laws of contract must also exist to govern the exchange of the commodity and the right to use that commodity. The specificity of contracts will depend upon the other assumptions of any model. For example, if information is perfect and there is no uncertainty as to default in the terms of trade, provision need not be made to specify recourse for breach of contract. It would be
known with certainty at the initiation of exchange that all terms would be met. Or, agents may write contingent contracts that clearly establish the rules in cases of default. It is important to note that the imposition of prior rights may not be sufficient to handle all decision-making problems of agents. Prior rights must be enforceable by the legal system if they are to have any effect on individuals' behavior. But rights must not only be enforceable, they must also be enforced. In summary, prior rights will specify the exclusive ownership and rules of exchange for all commodities in an Arrow-Debreu sort of world.

Contingent rights pertain to those laws which are necessary in an imperfectly informed world to determine the distribution of property rights after an unforeseen event occurs. The existence of contingent rights thus implies that one or more of the prior rights' conditions are not met. Liability rules and the adjudication process are the means by which legal institutions determine the assignment of contingent rights. More specifically, contingent or *ex post* rights apply to a world where recontracting exists and is necessary. In an Arrow-Debreu world with prior rights, all decisions are taken and all contracts made once-for-all. Uncertainty and imperfect information do not present problems if contracts can be written to cover all uncertain events and contingent claims. There is no need for contingent liability or fault laws that determine rights in the case of unforeseen events or if contracts are broken. A world where all prior rights exist is static: there is no unforeseen technological change without appropriate insurance markets; and there is no need ever to redefine rights. Contingent rights apply
to an imperfect world where contingent contracts cannot be made ex ante because agents lack information.

It is assumed that contingent rights are necessary because transaction costs exist in the operation of contingent claims markets. As noted in Chapter I, the acquisition and dissemination of information is a transaction cost. There would be no need for contingent rights or legal institutions to define these rights if information were perfect. Private markets for risk bearing would arise to handle uncertain events given the delimitation of prior rights. The question is why insurance markets do not tend to operate when information is imperfect, that is, when prior rights are ineffective. Chapter III examines this question in detail. This chapter confines its analysis to prior rights.

One might also say that the determination of new rights falls into the contingent right category. New rights, like new goods, are difficult to deal with. Simply defining prior rights over all possible commodities does not solve the problem adequately. The existence of contingent rights also necessitates a legal adjudication system; some method of assigning claims and rights after the occurrence of an unforeseen event. Bargaining is not necessarily a feasible nor efficient method of determining rights when transaction costs are not zero.

There are two basic ways of introducing adjudication into economic analysis. The first, exemplified by Landes (1971) and Martin (1972), introduces a court or litigation system, where lawyers, judges, and juries are given objective functions. These groups are assumed to determine rights after an event on the basis of the evidence given by the
agents involved in a rights dispute and on certain prescribed sets of common and statutory law. Determination of rights by this approach is probabilistic and difficult to model. A second, more rigorous approach is taken by Diamond (1974a, 1974b) and Green (1974a). They are concerned with the effect of specific liability rules on agents' behavior. They examine the optimality of liability systems and attempt to formulate imperfect information problems by relating agents' activities prior to the unforeseen event to legal standards for these activities. They find that only certain types of liability rules and standards can lead to efficient equilibria. Chapter IV modifies Diamond's and Green's models to deal with certain types of externalities.

Given this brief discussion of rights, I shall examine the effect of prior rights on resource allocation in this chapter, then consider in Chapters III and IV market and nonmarket methods of analyzing contingent rights (respectively).

B. The Importance of Prior Rights in the Operation of Perfect Markets

1. The "Coase theorem"

Coase argued, in his discussion of the effect of property rights on resource allocation with externalities, that "It is necessary to know whether the damaging business is liable or not for damage caused since without the establishment of this initial delimitation of rights there can
be no market transactions to transfer and recombine them. But the ultimate result (which maximizes the value of production) is independent of the legal position if the pricing system is assumed to work without cost" (1960, p. 8). This statement and Coase's partial equilibrium example of the cows and corn has been interpreted by many economists writing about externality problems to mean that the assignment of property rights does not matter in the prescription of solutions for externalities from an allocative standpoint. Prior rights must be assigned to one party, but it is then asserted that the efficient equilibrium points reached by alternative assignments of property rights are identical regardless of who possesses the right. I will call this assertion the "Coase theorem". It can be shown that the "Coase theorem" does not in general lead to the conclusion that efficient equilibrium points are unaffected by variable property rights. Coase's result is a special case. There is no guarantee that his solution will be obtained under our usual assumptions made in utility and profit maximization models.

There has been considerable debate over what Coase did and did not actually say. The question is whether the "Coase theorem" was actually asserted by Coase. His partial equilibrium example concluded that the same equilibrium point is attained independent of the assignment of prior rights to the farmer or the rancher. The problem is that Coase had no formal model and his arguments were based on many implicit assumptions. In dealing with a problem such as externalities which do not fit nicely into the competitive framework, one has to make explicit assumptions about agents' behavior, and what constitutes an equilibrium. Coase
and many of his followers have failed to specify the objective functions
of the parties involved in an externality, the behavioral assumptions,
and the possible equilibria.

Coase must make the following assumptions to obtain the results
indicated in his cows and corn example: perfect competition in all
markets, perfect divisibility of all factors of production and products,
zero transaction costs (in the assignment of rights and bargaining
process), and the existence of rents. His example considers only two
firms who both operate in different competitive factor and product
markets (yet both firms earn rents). All other firms in the two indus­
tries are unaffected by the externality (straying cattle in Coase's
case). The two firms bargain privately and the solution attained is
assumed to have no effect on relative prices in the respective industries
of both firms. Coase therefore has a very partial type of analysis.
He did acknowledge that the assignment of prior rights would matter when
transaction costs were considered. He did not elaborate formally on how
transaction costs affect resource allocation, nor on the relationship
between externalities and transaction costs. He implicitly recognized
the importance of property rights as prior rights that are necessary for
the operation of markets, but he did not explain clearly how rights
affect resource allocation.

I will not reproduce Coase's numerical example, but shall indicate
some of the problems with his analysis. Note that externalities appear
as mysterious aberrations in Coase's analysis. We do not know how an
externality could possibly arise in a world which satisfies Coase's
implicit assumptions. Coase thus helped to establish the traditional externality framework (discussed in Chapter I). He merely assumed that externalities exist, yet incorporates assumptions inconsistent with the presence of externalities.

One can criticize Coase on many grounds; his "model" is imprecise, e.g., were both firms maximizing profits before the change in the legal rule, is there free entry and exit, what happens if the externality and rights pertain to a factor that is paid its marginal product (does not earn rents), what happens in a general equilibrium context, etc. The assumption of rents for example, is crucial to Coase's analysis. Once the assignment of rights is made, Coase's bargaining method requires the party without the rights to pay the party with the rights if he wishes an increase (or decrease) in the level of the good generating the externality. This transfer must be a pure rent if we are to leave relative prices unaffected and keep both firms in their respective industries in this partial equilibrium world. The firm without the rights must be earning rents prior to the transfer. If not, and he was in long run equilibrium prior to the introduction of the externality, the payment to the other firm (or effect of the externality if he is the damaged party) will eventually drive him out of the industry as his average costs will be greater than the competitive product price prevailing in the industry.

I would also like to discuss briefly the problem of choosing an origin in the analysis. It is important to recognize that in most real world externality cases, prior rights reside de facto with the agent generating the externality. If this were not so, we would not observe
the external effect. The original position in any externality case, the status quo, thus has a positive level of the externality (e.g., a pollutant) and the rights vested with the polluter. Coase and others discussing property rights take the status quo as the origin in any situation, then discuss whether altering the rights affects resource allocation. In Coase's farmer-rancher example there exists, no matter who is liable, a positive number of cows capable of stomping crops. Coase makes the argument that the externalities are reciprocal in the sense that not harming one of the agents involves harming the other. Reciprocity, however, makes sense only if we start from a status quo position where the externality already exists. The status quo position is thus not defined properly with regard to prior rights. Prior rights should cover (by definition) the initial determination of endowments. If the pollutee has the rights to water in a certain locale, then a priori there is no water pollution. Ownership of rights specifies that the polluter must pay the owner of the water rights to engage in activities that pollute the water. If the polluter owns the rights to the water, a positive amount of water pollution exists and the pollutee must pay if he wants to decrease the amount of pollution. Thus the equivalent set of alternative property rights is either a status quo with zero pollution in which the polluter must pay to increase the amount of pollution, or a status quo with positive pollution in which the pollutee must pay to decrease the amount of pollution. Of course this rights assignment is still not specific enough as it says nothing about the enforcement of one's rights. We must therefore assume that the prior rights convey the power to compel the other party to pay either to increase or decrease the pollution, and that there are
The choice of property rights determines the choice of the origin.

By introducing variable prior rights, Coase has thus created an environment that requires some form of bargaining theory to derive a determinate solution or solutions. My basic quarrel with Coase is that he sketched only one possible result, using a very specific and partial example. Many of his followers (Turvey (1962), Davis and Whinston (1962)) then interpreted Coase's example to mean that alternative delimitations of prior rights would yield identical equilibrium points under more general models. Thus one did not have to worry about who had the rights. This generalization of Coase is invalid. If one interprets Coase as saying that efficient allocations can be reached with a prior right on either the afflicted or generating party (given Coase's assumptions), but that the actual equilibrium point reached with any given right is different, then I would accept the "theorem". But Coase in no way proves this assertion.

2. The Effect of Prior Rights on Attainable Equilibria

I shall now reformulate the Coase argument and present a model that attempts to preserve the Coasian framework, yet clearly distinguishes between the set of attainable equilibria and the equilibrium point actually reached under alternative assignments of prior rights. Starrett (1972) has also recognized the importance of the choice of origin in externality cases. He was not concerned with the invariance of property rights and derived efficient equilibria without distinguishing between the equilibrium points.
The question is, will the prior right that allows no externality and requires that the generator must pay the victim to engage in an activity that gives rise to an externality lead to the same allocation of resources (equilibrium point) as the prior right which allows positive levels of the externality so that the victim must pay the generator to decrease the externality? The problem is still not specified fully. That is, to know precisely what would happen to resource allocation under alternative prior rights, we would need to know how the externality affected both agents, and why the externality exists. Coase merely asserts the existence of an externality, and so do I in this section.

One method of dealing with the invariance of rights is to utilize a bargaining model that incorporates specific assumptions about prior rights. Fortunately, a bargaining model exists that can be adapted to deal with the case of an external diseconomy (e.g., pollution) under alternative assignments of prior rights, zero transaction costs, and perfect information. I will use the models developed by Dolbear (1967) and Shibata (1971) to show for the case of an external diseconomy that the "Coase theorem" does not hold except by chance.¹

Let there be two consumers, A and G, with quasi-concave utility functions defined over a vector of goods, \( X_i \), \( (i = 1, \ldots, j, \ldots, n-1) \), and \( X_n \), such that

¹ There is also a possible problem with nonconvexity of preferences in consumption and nonconvex production sets with production externalities. See Starrett (1972) and my discussion of nonconvexities in Chapter III.
\[ U^A = U^A(x^A_1, x^A_n) \] (1)
\[ U^G = U^G(x^G_1, x^G_n) \] (2)

where \( x^A_i \) and \( x^G_i \) are, respectively, A's and G's share of good i, that is, \( x^A_i + x^G_i = x_i \). \( x^A_i \) is an externality generated by G and consumed by A, therefore, \( x_n = x^A_n = x^G_n \). Consumers are required to reveal their preferences completely and accurately. It is then assumed that there exists a transformation function (or production possibility curve) that is linear, exhibits constant returns to scale, is continuous, and is the boundary of a convex production set.\(^1\)
\[ F(X_1, X_2, \ldots, X_j, \ldots, X_n) = 0 \] (3)
\[ (i = 1, 2, \ldots, j, \ldots, n). \]

Factors are assumed to be supplied inelastically and are owned by the two individuals. It is G's consumption of good \( x^G_n \) that generates the externality to A and the \( x^G_n \) in equation (3) is actually \( x^G_n \). That is, only the \( x^G_n \) that G consumes has a market in this model. \( x^A_n \) has no market. For completeness, we could distinguish between good \( x^G_n \) and the externality, e.g., A consumes loud noise, \( x_z \), when G plays his radio (good \( x^G_n \)); \( x_z = g(x^G_n) \). This specification clarifies the role of the externality but its introduction would not alter the general results of the model as \( g(x^G_n) \) is only a linear or multiplicative transformation of \( x^G_n \). Thus the externality only affects the market for the exchange

\(^1\) Constant returns to scale is a simplifying, but not necessary assumption. Linearity is however necessary, as it preserves the partial equilibrium nature of the Coasian framework by imposing fixed product prices.
of commodity $X_n$. All other markets are assumed to be perfect. The production of $X_n$ is unaffected by the externality. The special assumption of a linear transformation function eliminates the general equilibrium effects in the product and factor markets. We therefore have a general equilibrium framework that has been restricted by assumption to analyze the "Coase theorem" in the spirit of Coase's own explicit and implicit assumptions.

Before the explicit introduction of prior rights, $G$ is consuming good $X_n$ (e.g., playing his radio) and maximizing his utility independent of $A$. The de facto prior right is thus that $G$ has the rights to noisy radio-playing; the status quo is a positive amount of noise pollution. The efficient equilibrium for $G$ (ignoring $A$) is at the point where $G$'s marginal rate of substitution between goods $X_j$ and $X_n$ is equal to the marginal rate of transformation between the two goods. When $A$'s preferences are included in the determination of an equilibrium, the efficient equilibria are defined where the sum of the marginal rates of substitution for goods $X_j$ and $X_n$ for individuals $A$ and $G$ are equal to the marginal rate of transformation.\(^1\)

The private equilibrium for $G$ is determined from the constrained maximum problem:

$$\text{maximize } U^G(x^G, x_n)$$

subject to the linear transformation function

$$X_j = X_j + bX_n.$$ 

The first order conditions are

$$u^G_{x_j} + \mu = 0$$

$$u^G_{x_n} + \mu b = 0$$

---

\(^1\) This equilibrium condition defines the private equilibrium for $G$.
which yields \( \frac{u_G}{x_j} / \frac{u_n}{x_n} = b \), or the marginal rate of substitution equals the marginal rate of transformation (where \( u_G \) represents the derivative \( \frac{3u}{8x} \) and similarly for other partial derivatives). If \( X_n \) was a private good, the efficient equilibrium would be where

\[
\frac{u_G}{x_j} / \frac{u_A}{x_n} = \frac{u_A}{x_j} / \frac{f}{x_n}.
\]

But if \( X_n \) is an externality, the problem becomes: maximize

\[
U^G(x_j, x_n)
\]

subject to

\[
U^A - U^A(x_j, x_n) = 0 \\
X_j = X_j + bX_n.
\]

The first order conditions are:

\[
\frac{u_G}{x_j} + \frac{\mu}{x_j} = 0 \\
\frac{u_G}{x_j} + \frac{\lambda u_A}{x_n} + \frac{\mu b}{x_n} = 0 \\
\frac{u_A}{x_j} + \frac{\mu}{x_j} = 0.
\]

Eliminating the Lagrange multipliers and substituting yields:

\[
\frac{u_G}{x_j} / \frac{u_G}{x_n} + \frac{u_A}{x_j} / \frac{u_A}{x_n} = b.
\]

The efficiency condition is thus that the sums of the marginal rates of substitution between \( X_j \) and \( X_n \) must equal the marginal rate of transformation between \( X_j \) and \( X_n \).
Pareto optima for public goods, as was first recognized by Samuelson (1954). There are two important points to make about the Samuelson condition. First, there is no unique Pareto optimum; many efficient equilibria are also Pareto optima. The locus of these Pareto optima comprise a contract curve. Selection of one of these points on the contract curve thus requires a social welfare function (or dictator) that ranks the welfare of each party. Secondly, if the contract curve is not a vertical line, different amounts of the public good will be consumed at each equilibrium point. The amount of the public good consumed and the relative price of the public and private good are thus not independent of the origin or starting point: the initial endowments of the individuals. And we assume that prior rights determine the individuals' initial endowments; the delimit the origin in any negotiation.

A geometric representation of a bargaining model with externalities will illustrate the importance of prior rights. The Edgeworth-Bowley box diagram is modified to adapt Shibata's model to the case of external diseconomies. Individual G is assumed to have convex preferences, if we were considering two goods which were marketed, homothetic and identical preferences for each individual consuming those goods would guarantee that the same proportion of the goods would be consumed at each point along the contract curve at the same relative price ratio. In this case, the relative prices of the two commodities in equilibrium are independent of the initial endowments of the individuals. Although we can impose homotheticity on both A and G, it is not sufficient to guarantee a vertical contract curve. One way in which a vertical contract curve can be obtained is to assume that, for a fixed level of $X_n^j$, the marginal rate of substitution between $X_n^j$ and $X_n$ is constant for both A and G. This assumption would imply a zero income elasticity for good $X_n$ and is thus a very strong assumption.
illustrated with indifference curves of the usual shape (Figure I) defined over a numeraire, $j$, (for all private goods) and the good generating the externality, $X_n$. Individual A's indifference curves are positively sloped, indicating that the more of good $X_n$ he has (e.g., the more noise), more of the numeraire good is necessary to maintain a given level of utility (Figure II). Each individual is assumed to have an initial endowment of income, measured in terms of the numeraire, $X_j$ (depicted as a and b in Figures I and II). A transformation function between the good generating the externality and the numeraire is assumed to be linear (Figure III). The $X_j$ intercept of the transformation curve is the combined income of A and G.

![Figure I](image1.png)

![Figure II](image2.png)

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1 The transformation function could also be nonlinear. As long as it is convex, the results will not vary from the linear case. Nonlinearity provides explicit consideration of the possible redistribution of income through factor shares. This would however take us away from Coase's propositions.
Because of the publicness of $X_n$, the amounts of this good (or bad) consumed by A and G are identical. The horizontal axes of Figures I, II, and III therefore have the same scale and it is possible to combine the figures into one diagram. Following Shibata, this is accomplished by transforming A's indifference map. The $X_n$ axis of A is rotated around the origin until its slope is equal in absolute value to the slope of the transformation function. All of A's indifference curves must then be adjusted to this new $X_n$ axis (call it $X_n$), to maintain the same level of utility (the dashed curves in Figure II). This adjustment process means that the slope of A's indifference curves at any point is now equal to

$$\frac{u_A^{X_i}}{u_A^{X_n}} + \frac{f_{X_j}}{f_{X_n}}.$$ 

The reason for adjusting A's indifference map is thus to yield directly the Samuelson efficiency conditions when A's and G's indifference curves are tangent.

Now we invert A's map and superimpose the section above and including the adjusted origin on to G's indifference map. The $X_j$ axes now coincide

Note also that A's adjusted indifference curves must now be everywhere steeper than the transformed $X_n$ axis.
as do points a and b. This procedure produces a diagram (Figure IV) with the same production possibility relationship as Figure III and has characteristics analogous to the Edgeworth-Bowley box. \( G^0A \) shows the total endowment of both individuals and point F indicates the distribution of income (in the form of \( X_j \)) between A and G. Any point on the diagram (e.g., point E) shows how much of the numeraire each individual has (OJ for G and JJ' for A) and their joint consumption of the good generating the externality for G and the externality for A (ON). Each individual must exhaust his income and thus the total consumption of \( X_j \) must add up to a point on the transformation curve. Line CC' is the locus of tangency points between G's indifference curves and A's adjusted indifference curves, showing a possible set of Pareto optimal allocations of \( X_j \) (for A and G) and \( X_n \). Notice that the slope at each tangency point along the contract curve is different. Thus the relative price of \( X_j \) to \( X_n \) will vary depending on the location of the individuals within the box.

Figure IV
Given an initial position, the diagram will indicate a locus of possible outcomes: it cannot predict where the final equilibrium (if there is one) will be reached. As Shibata points out, "it is at once clear from our diagram that the situation at hand is essentially one of indeterminate bilateral monopoly ... Economists customarily have have very little to say about pure bargaining situations in which the outcome is dependent upon interactions among only a few parties" (1971, p. 9). This is precisely the situation which Coase has postulated with his cows and corn "model". At this point, we need to return to the assumptions about prior rights.

I assume that there are two alternative assignments of prior rights defined over good $X^1_n$. If $G$ possesses the prior rights to $X^1_n$, it implies that the origin for bargaining is a positive amount of $X^1_n$ (e.g., point E) and that $G$ will decrease his consumption of $X^1_n$ only if he moves to a higher level of utility (a higher indifference curve). If $A$ controls the prior rights for $X^1_n$, the origin is zero consumption of $X^1_n$ (e.g., point F), and $A$ will allow $G$ to consume $X^1_n$ only if $A$ moves to a higher indifference curve. This information about prior rights

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1 Intermediate cases are possible, e.g., party $G$ may have the rights to use a limited amount of the good generating the externality and be constrained beyond some point, where $A$ then has the rights to prevent further use. The common law of nuisance applies to these cases, i.e., a party is allowed to pursue an activity up to the point at which it is believed to harm others. The crucial question with nuisance laws is what constitutes harm. Coase's extensive discussion of legal cases provide many examples of possible interpretations of nuisance by the courts. No one has yet (to my knowledge) investigated the effect of precise or imprecise nuisance laws on agents' behavior in an economic model.
does not enable us to predict the exact outcome of any negotiation between A and G as we have not specified the transaction costs of bargaining. If we assume that transaction costs are zero, we can illustrate one possible outcome of bargaining with alternative prior rights that differs completely from the conclusions drawn by Coase and his interpreters.

In Figure IV, the two initial points depicting the alternative rights are E and F. If we start at point E, individual G will accept a move only to a point such as E' on a higher indifference curve. He will decrease his consumption of \( X_n \) in exchange for an increase in \( X_j \). Individual A will give up some of his \( X_j \) to achieve a decrease in \( X_n \), as he does not decrease his utility by doing so. As the two individuals' indifference curves are tangent at point E', they are at a Pareto optimum. Similarly, if we start at point F, individual G will give up some of his \( X_j \) to A to consume \( X_n \). A will accept because he can then move to a higher indifference curve. Both individuals will then move to point F'. Pareto optima can be achieved under either prior right assignment, but the efficient points which are reached are different.

Compare points E' and F'. The relative prices of \( X_j \) to \( X_n \) are not identical at E' and F' and the quantity of the externality consumed by both parties is different.\(^1\) In the case illustrated in Figure IV, the relative price of \( X_j \) to \( X_n \) is greater at point F' than at E'. If

\[ X_j \]

As noted before, the only way we can obtain identical relative prices of \( X_j \) to \( X_n \) is if the contract curve is a vertical line. I can find no general conditions under which this solution will be obtained. See footnote 1, page 28.
we dropped the assumption of a linear transformation function, the
effects of these different relative prices could be traced through the
factor and output markets. What we can conclude from this model is
that different impositions of prior rights do affect relative prices,
the amount of the externality consumed at Pareto optimal points, and
hence, resource allocation.\footnote{Mishan (1971) notes that changes in property rights leads not only to
different income distributions, but also to different levels of the
externality existing in equilibrium. He arrives at this conclusion,
using a comparison of compensating versus equivalent variation measures
of welfare gain. Unfortunately, his "model" is hampered by a lack of
specific assumptions. Also see McGuire and Aaron (1969) for further
verification of the non-uniqueness of a public good equilibrium.}

Although this bargaining model dealt with
consumption externalities, a similar approach to production externalities
should yield analogous results. Presumably there are assumptions under
which a vertical contract curve could be obtained with this approach,
e.g., through specific restrictions on prior rights or by imposing some
form of weak separability on preferences. The important point is that
the "Coase theorem" is not a general result, but depends on restrictive
assumptions not specified by Coase or any of his followers.

The "Coase theorem", properly restated, thus says that alternative
assignments of prior rights yield different but equally efficient
resource allocations. This "theorem" is still not very interesting or
useful in analyzing externalities as it says no more than is implied by
Pareto optimality with public goods. Given universal markets and rights,
and zero transaction costs, externalities are internalized. The revised
theorem does however imply that the assignment of rights \textit{a priori} cannot
be made on grounds of efficiency. Assigning rights determines whose interests count and which agents gain in any subsequent exchanges. It is therefore a normative problem in this ideal world.

A very interesting implication of this analysis is that schemes of auctioning property rights or licences to engage in an activity (e.g., establishing markets in licences to pollute) must take into account the \textit{ex ante} distribution of property rights, implicitly or explicitly defined. That is, does the pollution exist in the status quo or not? The bids for licences will depend on who has the \textit{ex ante} rights because rights affect income levels and distribution (budget constraints). If we were in a world where transaction costs existed, rights would also affect the transaction costs of operating markets for pollution licences. One would expect that alternative \textit{ex ante} distributions of rights will lead to different efficient licence bids and \textit{ex post} rights distributions. Thus licence schemes also involve normative judgment as to whose interests count. The status quo position cannot be ignored.

The inadequacy of the Coasian type of analysis to deal with specific cases of externalities defined in the context of market failure and legal institutions brings us back to a consideration of transaction costs and the legal rules that arise when transaction costs exist. The analysis in this chapter has thus not explained why externalities persist. I turn now to a discussion of imperfect information and externalities.
III. IMPERFECT INFORMATION: OPERATION OF CONTINGENT MARKETS WITH EXTERNALITIES

A. Introduction

This chapter considers the relationship between information and externalities. Part A examines the importance of information in the operation of markets and develops an information/externality taxonomy. Parts B and C concentrate on an analysis of two externality cases that arise from imperfect information. The basic questions asked in this chapter are whether private markets will operate with externalities and whether the resulting equilibria are efficient.

The introduction of imperfect information means however that our traditional notions of equilibrium, efficiency and optimality may have to be modified. We can no longer expect the same conditions for a competitive equilibrium to hold with imperfect information and externalities. Equilibria in the models presented in parts B and C of this chapter are generally characterized by a single price or set of prices that maximize the expected utility of an agent affected by the externality subject to a zero profit condition for insurers. The problem is that this sort of equilibrium is not too meaningful with imperfect information. First, the afflicted party's utility is maximized independent of the generating party's decisions about the externality. We may therefore attain equilibria that are not optima in the traditional sense. Secondly, we may be dealing with equilibria that are efficient only
relative to the information the agent possesses. As Rothschild notes (1973, p. 1301), "What equilibrium is in a particular market depends on what individuals in that market know". What we may want is equilibrium to be defined as a solution which is self-realizing, that is, when expectations are realized.\(^1\) Optima would thus be defined relative to the information possessed versus the information attainable. Optima may then be relative to the set of preferences established with imperfect information. The problem with equilibria of this sort is that they tend to be arbitrary and not unique. Secondly, it is difficult to determine what constitutes social improvement. We could, for example, define a social improvement to occur whenever one acquires more information. This follows from the assumption that preferences based on less information lead to less welfare than preferences established with more information. I cannot attempt to answer the questions of what constitutes equilibrium and optimality with imperfect information, but want to point out that some of the definitions contained in this chapter (and Chapter IV) will not necessarily be the traditional definitions made under the assumptions of perfect competition.

The traditional externality literature argues that externalities can be internalized by contractual arrangements, thereby eliminating the need for legal institutions to specify contingent rights (prior rights are still required for the operation of markets). All agents

\(^1\) See Spence (1973, 1974) for examples of market equilibria under a definition similar to this.
are assumed to negotiate costlessly with each other to achieve Pareto optimal resource allocations, given the externality. This argument may be invalid for two reasons. First, the externality cannot be a public good or bad. Private contracts will be inefficient if the externality entails collective harm due to problems of non-appropriability and non-revelation of preferences. Again, I will assume externalities are not public bads in this chapter. But even if externalities are private bads, private contracts may still lead to inefficient internalization of externalities if information is not perfect. The traditional argument must thus rely on the assumptions that no public goods or bads exist and that information is perfect in the sense that all agents are identically informed (i.e., their information corresponds perfectly to the true state of the world).

As Radner (1968) has shown, perfect information is necessary to guarantee contractual agreement. If information is perfect, contracts can be written to cover all possible present and contingent events (assuming no public goods) and all externalities will be internalized efficiently in a general equilibrium world as shown by Arrow and Debreu (1954, 1959).

In my framework however, externalities do not exist if transaction costs are zero. I have assumed that the acquisition of information is a transaction cost encountered in the operation of markets, and the presence of imperfect information implies positive transaction costs. Imperfect information is defined as information that does not correspond completely to the true state of the world, but represents an individual's prior distributions over what he perceives the state of the
world to be. Zero information thus means that the individual has no
priors over the state. Perfect information means that his beliefs
correspond to the true state. When information is imperfect, exter-
nalities may arise and private markets may fail.\footnote{Clearly, there are other causes of market failure: non-appropriability (public goods) is the major example. Because I want to concentrate on information problems with non-collective externalities, I will assume that the other possible causes of market failure do not affect the events and markets under consideration. See Crocker (1973) for an interesting discussion of the non-appropriable aspects of externalities. One could also compound the issue by noting that some pedlpeople\textsuperscript{e} (e.g., Arrow (1969)) argue that information itself has non-appropriable attributes. It is difficult to retain exclusive rights to information and to prevent non-buyers from acquiring the information. This argument is not totally convincing and therefore I will assume that non-appropriability does not compound information problems.} Given imperfect information, we can also no longer rely on prior rights to guarantee the operation of markets (see the definition in Chapter II, part A).

What are the precise relationships between externalities and information? Why may imperfect information generate externalities? These are not simple questions. First we must define what is meant by information. Secondly, externalities tend to be very case specific. That is, particular types of information may lead to different types of externality cases. There are no general cases or rules. I shall however develop an information taxonomy to distinguish some classes of externality/information cases.\footnote{The taxonomy developed in this section is by no means exhaustive. It merely defines some plausible cases and identifies the cases discussed in parts B and C of this chapter. Work on information has become quite extensive and other taxonomies and definitions have been developed. See for example, Rothschild (1973) and Stiglitz (1975).}
A necessary condition for the existence of externalities is that there exist technological interdependencies (or jointness) between the objective functions of economic agents. If these interdependencies give rise to a divergence between the private and social marginal valuations of the commodities affected by the interdependencies, an externality arises. I am not trying to explain why externalities arise, but rather, why they persist if competitive markets exist. Alternatively, I could ask why competitive markets fail when externalities exist. Certain types of externalities may persist because of imperfect information. Let us characterize imperfect information. Uncertainty is the term used to depict imperfect information about future or random events. Imperfect information in this case implies that the individual's probability distribution over the event does not equal the true distribution. Perfect information would of course imply that the individual knows with probability one (zero) that the event will (will not) occur. Interdependencies between individuals can thus be stochastic. Externalities can then enter individuals' objective functions in three ways. They can affect (1) the consumption or production possibilities in a future state; (2) the probability of a future state's occurrence; (3) both the consumption or production possibilities and the probability of future states. If externalities are stochastic and affect individuals in any

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I thus rule out cases such as defective products which do not harm individuals, but merely do not operate as expected. That is, where no divergence between private and social marginal cost exists, no externality arises.
one of these ways, we introduce the need for contingent contracts or markets to internalize externalities.

Imperfect information can also apply to uncertainty about resource endowments, individuals' preference orderings, and/or productive opportunities. Hirshleifer (1971) calls this technological information. Individuals may have imperfect technological information not only about occurrences in future states, but also those in present states of the world. Imperfect technological information compounds the uncertainty that arises when externalities are stochastic. Let us first see why technological information is important with externalities, then characterize a set of externality/information cases.

The difference between externalities and "normal" (non-externality) goods is that consumers may still be able to maximize their utilities (or firms, their profits) and achieve Pareto optimal equilibria without technological information about normal goods. This will not in general be true for externalities. Consumers, for example, need not have information about the technology of the production function for a particular good nor do they require information about other individuals' preferences for that good to be able to purchase the good in a

Hirshleifer (1971) also defined a term, market information, to cover cases where agents did not know supply and demand functions in a given market. Imperfect market information can compound the externality problems associated with imperfect technological information. I will however ignore the problems introduced by imperfect market information as I wish to concentrate on externality models incorporating only imperfect technological information.
competitive market (given no market uncertainty). If I wish to buy a stereo, I do not require information about electronics technology nor my neighbour's preferences for stereos. I can compute my marginal rates of substitution between stereos and any other normal good and satisfy the first order conditions for utility maximization without knowing how the stereo was produced nor how many my neighbour buys.\textsuperscript{1} With externalities, this exercise will simply not work. If the externality is botulism from improperly processed food, and I cannot identify which cans of green beans contain the botulism toxin, it is unlikely that a Pareto-optimal allocation of resources can be attained, nor that my own utility will be maximized.\textsuperscript{2}

Compare the first order conditions for an efficient equilibrium for normal goods with one for an externality (see Chapter II, pages 26-27 for the model). The equilibrium conditions for normal goods are that the marginal rates of substitution for all consumers between any pair of goods (assuming all goods can be ranked in preference orderings) are equal to the price ratios of these goods. With externalities, efficiency requires for all consumers affected by the externality, that the sum of the marginal rates of substitution between the externality

\textsuperscript{1} This is simply the two theorems of welfare economics. Note that we always assume no externalities exist in the proofs of the welfare theorems.

\textsuperscript{2} David Donaldson suggested this example to me.
and any normal good equal the price ratio.\(^1\) Thus any individual affected by the externality cannot maximize his utility independent of others also affected by the externality. All affected parties must therefore be able to identify each other and A must know G's preferences (or technology if A and G are firms). Traditional externality theory of course recognized that equilibria could be attained, but may not be efficient if externalities were present. What I want to emphasize is one reason why inefficiencies may occur: imperfect technological information. If agents do not have information about each others' technologies or preferences, competitive equilibria (if they exist) will tend to be inefficient and non-optimal. Technological information is thus a necessary condition for the existence of efficient equilibria with externalities. The point is that optimal allocations with externalities require involved agents to possess technological information; optimal allocations with normal goods do not.

Let us define technological information in the context of externalities more precisely. Recall that technological information pertains to all agents involved in an externality. I shall first distinguish between the generator(s) and of the externality (denoted by G) and the agent(s) affected by the externality (denoted by A). Let T be the set

\[ (\partial u_i / \partial u_j) = (\partial f_i / \partial f_j) \]

for all goods i, j and all individuals A, G. With externalities, the condition is that

\[ (\partial u_z / \partial u_j) = (\partial f_z / \partial f_j) \]

for an externality, z, and normal good, j, affecting all individuals, A and G.

\(^1\) Similarly, Pareto optimality for normal goods requires

\[ (\partial u_i / \partial u_j) = (\partial f_i / \partial f_j) \]

for all goods i, j and all individuals A, G. With externalities, the condition is that

\[ (\partial u_z / \partial u_j) + (\partial u_z / \partial u_j) = (\partial f_z / \partial f_j) \]

for an externality, z, and normal good, j, affecting all individuals, A and G.
of technological information (not a single variable), where $T_a$ shows the effect of the externality on the afflicted agents' consumption (or production) set, and $T_g$ is the technology (or preferences) of the generating party that is responsible for the creation of the externality. Take our botulism case as an example. $T_a$ could represent serious illness or death to afflicted parties, resulting in a decrease in consumption of some or all goods defined in the individual's utility function (or decreases the individual's income). $T_g$ could be a faulty cooking procedure or can-sealing process that allows botulism toxin to grow. We can now specify the possible set of information cases, distinguish between symmetric and asymmetric information, and identify the cases which give rise to externalities.

There are eight sensible cases that are illustrated in the following table (Table I). A + means that the individual has perfect technological information, while a 0 means that the individual has imperfect or no technological information. The information is *ex ante*, i.e., it depicts the technological information each group has prior to the operation of any market.

---

1 Alternatively, the effect could lead to an increase in the consumption of goods like medical care and decreased consumption of all other goods. The important point is that the consumption set of the afflicted party is altered by the externality. $T_a$ is the technological information about these effects (e.g., A's marginal rate of substitution between the externality and normal goods).
<table>
<thead>
<tr>
<th>CASE</th>
<th>INDIVIDUAL</th>
<th>( T_A )</th>
<th>( T_G )</th>
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<tbody>
<tr>
<td>(1)</td>
<td>A</td>
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<td>G</td>
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<td>A</td>
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<td></td>
<td>G</td>
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<td>(3)</td>
<td>A</td>
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<td>(4)</td>
<td>A</td>
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<td>(5)</td>
<td>A</td>
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<td>G</td>
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<td>(6)</td>
<td>A</td>
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<td></td>
<td>G</td>
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<td>(7)</td>
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<td>(8)</td>
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<tr>
<td></td>
<td>G</td>
<td>0</td>
<td>+</td>
</tr>
</tbody>
</table>

Table I: TECHNOLOGICAL INFORMATION CASES

I call cases (1), (2), and (3) symmetrical technological information. That is, both groups know everything about each other's "technologies", they know nothing, or they each know only their own technologies. Case (1) depicts the perfect information assumption made in most economic models. If we interpret the zeros in case (2)
to mean no information (not even imperfect), then Radner (1968) has shown that no private market will exist for the exchange of the commodities to which the information pertains. No exchange is possible unless one introduces other agents (or a government) that provides information to A and G. Exchange may also be possible if we introduce technological change (disembodied) that both parties can acquire.

Case (2) with zero information is thus not very interesting for the purposes of my analysis. If we interpret case (2) as implying imperfect information, market exchange may be possible and self-realizing equilibria may be obtained. Case (3) simply indicates that individuals in group A only know how the externality affects them, but do not know how it is generated, i.e., they do not know G's productive technology or preferences. And conversely, G's know only their own technologies or preferences, but not how the externality they generate affects the A's.

Cases (4), (5), (6), (7), and (8) depict asymmetric information.

I rule out seven other possible asymmetric combinations with the

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1 See Hirshleifer (1971) for a discussion of the "social value" of publicly provided technological information in a pure exchange model. Unfortunately, Hirshleifer's discussion does not clearly define social value nor distinguish between ex ante and ex post valuations of information. Also see Marshall (1974).

2 We could make cases (2) and (3) asymmetric if we interpret the zeros to mean imperfect information and assume that A's and G's prior distributions are unequally correlated with the true state. That is, A's information may be more (or less) representative of the true state than B's information.
assumption that an individual cannot have more technological information about the other group's functions than he has about his own functions.

One combination remains:

\[
\begin{array}{cc}
T_A & T_G \\
A & + & + \\
G & 0 & 0 \\
\end{array}
\]

This situation seems unrealistic. It is unlikely that afflicted parties can ever know more about the externality than the parties responsible for generating the externality.

Externalities can emerge with any of the cases except (1). If perfect information exists (and all other assumptions of perfect competition are met) then no externalities can exist. All will be internalized efficiently through bargaining or the operation of perfect markets. Once we introduce imperfect information, it is no longer certain that either bargaining or markets (if they exist) can lead to efficient competitive equilibria. Just how imperfect information affects the competitive solution is examined in parts B and C of this chapter.

I have already explained why case (2) is not very interesting in an analysis of private markets. By an analogous argument, (4) and (6) are also rather uninteresting. If A does not know about the existence of an external diseconomy generated by G, G is unlikely to engage in any transaction with A that reveals the presence of the externality. In case (5), A has an incentive to exchange with G, but if G cannot tell how he's generating the externality, he is unlikely to trade. (3), (7), and (8) are similar in that each group has at least
technological information about their own functions.

Our information taxonomy can now be complicated by adding uncertainty to the technological information table. This would increase to fourteen the number of possible cases if we assume only two possible situations for A and G. Either both parties are uncertain about the externality's occurrence (and their probability distributions need not be identical), or G knows when the externality occurs with certainty, but A does not. These cases follow from the assumption that the G's have more information about the probability distribution for the externality than the A's. Therefore, if G is uncertain about the occurrence of the externality, A is also. G may have perfect information about the event, A may not.

We could also combine the technological information cases with the three ways in which externalities as stochastic events affect agents' objective functions. Rather than pursue this exhaustive taxonomy, I will define the two cases which are examined in parts B and C of this chapter. I call the two cases stochastic externalities and information externalities. In a stochastic externality, the externality (or the commodity which generates the externality) is assumed to enter the objective function of the afflicted agent as an argument of his utility function. If, for example, the afflicted agent is a consumer, the externality, z, is assumed to enter his utility function in a particular state. Let there be two states, in which the externality exists in one state, but not the other. We then have a stochastic externality when

\[ U^* = \pi u(c_1, z) + (1 - \pi) u(c_2). \]
That is, expected utility is contingent upon the individual's state-dependent utility, where utility in state one is defined over the commodities the individual would consume in state one \((c_1)\) and the externality. The externality does not affect consumption if state two occurs. I assume that technological information is perfect.

An information externality occurs when the externality enters the individual's expected utility calculation as an argument of the probability of a given state's occurrence. That is,

\[
U^* = \pi(z)u(c_1) + [1 - \pi'(z)]u(c_2).
\]

The externality is still a random event in that the individual does not know whether state one or state two will occur, but the externality now influences his expected utility by affecting the probability of the occurrence of the states. We therefore must multiply his utility in both states by a probability function, \(\pi(z)\), where the afflicted individual cannot control \(z\). Expected utility is again dependent on which state occurs. Technological information is assumed to be imperfect and is represented by case (3). The afflicted agent knows his own technology, but not the generating party's technology, and the generating party knows his own technology, but not that of the afflicted party.

Examples can be derived from our botulism case. In a stochastic externality, cans containing botulism toxin enter the afflicted agent's utility function if state one occurs. In an information externality, it is the activities of the generating party that may lead to the creation of cans containing botulism toxin. These activities (e.g., monitoring the can-sealing process) thus affect the probability of
finding botulism in cans. The utility function for each state must therefore by multiplied by a probability function, dependent on these activities, rather than merely the afflicted individual's own probability distribution for the state. We could also include the externality in the afflicted agent's utility function for an information externality, but refrain from doing so for simplicity.\(^1\) The externalities are thus stochastic in both cases in that individuals have a probability distribution over the occurrence of the externality, but the technological information and the manner in which the externality affects individual's objective function varies.

In parts B and C, I also introduce financial intermediaries (insurance companies). With stochastic externalities, I assume that the insurance companies also have perfect technological information about A and G. In the information externality case, I assume that insurance companies do not have technological information about either A or G.

Given imperfect information, prior rights may not be defined over all commodities, that is, they are not comprehensive and may also be non-exclusive. The question is, who has the rights over the externality? Both agents are affected by the externality (in opposite directions), yet the agent producing it possesses the prior rights de facto if the externality exists (see Chapter II). The problem is that externalities

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\(^1\) We would then have to distinguish between the \(z\) that occurs in the probability function and the \(z\) which enters the utility function. I do not distinguish the \(z\)s, again for simplicity of notation.
arising from imperfect information may violate some or all of the conditions for prior rights. Externalities can arise from imperfect information, and given the imperfect information, prior rights may no longer exist.

The question is now what institutions will arise (if any) to allocate resources given imperfect information and externalities? Three possible alternative institutions may arise: (1) the emergence of contingent claims (insurance) markets; (2) legal institutions which assign contingent rights; and (3) vertical integration (for externalities that only affect firms). I shall examine and compare possibilities (1) in this chapter and (2) in Chapter IV with respect to their ability to internalize externalities efficiently. Each alternative will be discussed generally, then formulated more precisely.

B. The Operation of Contingent Markets with Stochastic Externalities

In section A of this chapter, I argued that externalities may persist if information is imperfect. In this section, I shall examine stochastic externalities, that is, externalities that enter an individual's expected utility calculation as an argument of his utility function in a particular state. Uncertainty describes certain types of externalities

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1 See the articles in the Bell Journal of Economics and Management Science 6 (Spring 1975), and Green (1974b) for a discussion of information as a stimulus to vertical integration. I will not deal with this topic in this thesis.
and, even in this relatively simple framework, externalities may prevent the operation of a contingent claims market. In general however, I find that the stochastic externalities examined in this section do not lead to market failure.

Let us consider the stochastic case where the externality is a random event and all agents have perfect technological information. The event occurs when one agent inadvertently produces an output that may affect the production or consumption possibilities of another agent, and hence the event becomes an externality. It is assumed that: (1) the externality is a random occurrence, (2) the generator knows his technology, but has no control over the occurrence of the externality, (3) the afflicted party knows precisely the effect of the externality on his own production or consumption possibilities and therefore on his expected income. The uncertainty only pertains to the occurrence of the externality. I will model this stochastic externality with the state preference approach to uncertainty and confine my example to a situation where an individual (as opposed to a firm) is affected by the externality.  

Given two possible alternative and mutually exclusive states, $S_1$ and $S_2$, an externality can be said to occur if, for example, $S_1$ occurs. There is no externality in $S_2$. The afflicted party knows how $S_1$ affects his utility function and is also assumed to have a probability distribution defined over all possible states. As long as the afflicted party

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1 See Arrow (1964) and Hirshleifer (1965) for the development of the state preference model.
cannot affect the probability of any state's occurrence, the nature of the distribution is unimportant in that it does not affect the individual's expected utility maximizing solution. Possible examples of stochastic externalities include the botulism case in part A and other product defects that injure consumers of these goods, and sporadic emission of toxic wastes into rivers that affect downstream firms. I will not consider cases of stochastic externality that involve collective harm. The question is, will contingent markets exist to internalize the stochastic externalities?

The formal equivalence in theory between certainty and uncertainty depends on the assumption that contingent contracts can be written to cover all possible uncertain events. That is, individuals can guarantee (by purchasing positive or selling negative contingent claims) a specified level of income in all possible states of the world given certain knowledge of all present and future prices (i.e., there exists no market uncertainty). With stochastic externalities, we are thus in an Arrow-Debreu world, where information is not considered explicitly; technological information is assumed to be perfect. The uncertainty pertains to which of S future states will occur. Expected utility is dependent upon which state occurs, but it is assumed that an individual knows what his income and consumption will be in the alternative states, because in time zero, the individual purchases (or sells) claims to commodities in all future states. We know from Arrow (1964) that if there exists a competitive economy with N individuals, X commodities, and S states, then SX contingent claims must have markets (SX markets) to achieve an optimal
allocation of risk-bearing.¹

This section entails an examination of insurance markets as a specific example of a contingent market and set of contingent contracts. I employ insurance markets as a particular example of an institutional response to uncertainty rather than work in the more abstract framework of contingent claims models for several reasons.² First, we generally make the assumption that any two individuals will not exchange contingent contracts unless both are made better off by the exchange.³ If the two individuals are A and G, we would not expect them to engage in any contingent contracts unless prior rights were delimited. If no prior rights exist, no exchange between the two parties is likely. This

¹ Arrow (1964) also attempted to show that only (S + X) markets would be needed if there are X spot markets which open when a particular state occurs and there are S independent money claims to commodities. See Nagatani (1975) for a refutation of this theorem.

² Other markets and institutions have developed to deal with uncertainty (and some information problems), e.g., the stock market and cost-plus contracts. I shall not deal with these markets as they are not applicable to externalities. It also should be noted that insurance markets really are not necessary for the analysis in this section. I employ them now because they are necessary for the analysis in part C of this chapter and I wish to create a basis for comparison.

³ Imperfect information can seriously interfere with this rationality assumption. If agents have imperfect information, they may enter contracts in which they perceive ex ante that their welfare increases, but are disappointed ex post. Again, we can get around this problem by re-defining equilibria and welfare improvements under imperfect information. The market will be said to be in equilibrium when one's expectations are realized. And, this will constitute an improvement in welfare relative to the information each agent has.
argument of course holds for any commodity, not just contingent commodities. But, as argued in section A of this chapter, we would expect that fewer prior rights exist for contingent commodities (e.g., stochastic externalities) than for ordinary goods. If prior rights exist and are assigned to either A or G, private contingent contracts between them are possible (given perfect technological information). Note however that there is no reason to expect that identical efficient outcomes would be obtained with different assignments of prior rights. The introduction of uncertainty should not alter the result obtained in Chapter II. If no prior rights exist, afflicted parties may still seek some sort of contingent contract. We might then expect that a financial intermediary (e.g., insurance company) may emerge to sell contingent claims.

Insurance companies may also arise to economize on the transaction costs of operating a market. If there are scale effects (increasing returns) individuals may be too small to engage in efficient bilateral contracts. There may also be asymmetries in the risk-bearing ability of the A's and G's. This possibility is especially relevant in cases where the A's are individual consumers and the G's large corporations. In the botulism case, for example, one could argue that the corporation which produces the leaky cans would, because of the size of its assets, be able to insure an individual consumer at lower cost than could the individual insure the corporation. If both A and G are small, then either may seek to diversify his risk by purchasing insurance from a financial intermediary which can spread its risks over many contingent
commodities. I argue therefore that because of the possible lack of prior rights and the presence of transaction costs, we should consider insurance markets rather than bilateral contracts between A's and G's as the probable institutional response to stochastic externalities.

Let us now ask the question: will insurance markets arise to deal with stochastic externalities? If so, will competitive equilibria be attained? From Arrow (1964, 1974) and others (Smith (1968), Ehrlich and Becker (1972)) we know that if there is perfect technological and market information, an optimal insurance contract can be written over random events as long as the insurance industry is perfectly competitive, the insurer can determine the actuarial value of the uncertain event (risks can be reduced to a statistical basis), and individuals maximize their expected utility.\(^1\) I shall use the results of the optimal insurance models of Arrow (1974) and Ehrlich and Becker (1972) to develop a model for stochastic externalities. The structure of the analysis is as follows. I first model stochastic externalities in the optimal insurance framework. I then explain the limitations of the model; why certain assumptions are implausible.

Insurance models are generally based on the principal-agent relationship; the agent (insurance seller) maximizes his profits by

\(^1\) It might seem peculiar to assume that the insurance industry is perfectly competitive when transaction costs exist. We shall ignore this inconsistency for the moment as our transaction costs are merely no prior rights and marketing costs. I show however in part C of this chapter that perfect competition is inconsistent with transaction costs when those transactions costs are imperfect information.
maximizing the utility of the principal (insurance buyer). It is generally assumed that the risk insured against is loss of income or loss of utility measured by an income equivalent (or consumption set) in alternative states of the world. The insurance policy specifies a cash or kind reimbursement (payment) for each state of the world. Insurance policies are constrained by two assumptions: (1) the insurer is assumed to be risk neutral and premiums therefore only depend on the expected insurance payment to the principal; (2) insurance payments are non-negative. It is then assumed that the insured knows the objective probabilities of all states, his pre-insurance income in all states, and possesses a utility function defined over consumption in each state. With stochastic externalities, utility will vary with the state, i.e., utility is state-dependent.

I shall assume initially that prior rights exist and are assigned to the generating parties. They will thus demand no contingent contracts. Afflicted parties, on the other hand, will want to insure against the occurrence of the externality to equalize their expected utilities in all states. Afflicted parties are assumed to be risk averse. Let us consider a single afflicted party, $A$, and how the introduction of a stochastic externality affects his demand for insurance. I assume that

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1 Arrow (1974) rationalizes non-negative insurance payments on moral hazard grounds and argues that it may be difficult to collect a payment from an individual in states with favourable outcomes. This argument is not entirely convincing as the information requirements of this model would not be inconsistent with positive and negative insurance payments.
A is a representative individual in that the externality affects all A's identically. This allows us to calculate one equilibrium price that is common to all afflicted parties.

Consider a simple case where individual A is faced with the problem of maximizing his expected utility given two uncertain states, 1 and 2. His utility function in each state is assumed to be strictly concave. Utility in state 1 is a function of his own expected consumption, $c_1$, and the consumption of another individual, $c_G$. Utility in state 2 is a function only of individual A's consumption in that state, $c_2$. $c_G$ is the stochastic externality. Both states are of course weighted by the probabilities of their occurrence, $\pi$ and $(1 - \pi)$. Thus the expected utility of A* $(U^*)$, is state-dependent and in one state, A's utility is dependent upon the consumption of $G$, the generating party. Individual A (in period zero) then maximizes his expected utility over states one and two (in period one). That is, he maximizes

$$U^* = \pi u^1(c_1, c_G) + (1 - \pi)u^2(c_2)$$

subject to his budget constraint

$$p_1 c_1 + p_2 c_2 = k$$

where $k$ is a parameter equal to initial wealth minus consumption in period zero. $p_1$ and $p_2$ are contingency prices that prevail in period zero, and may not be the prices which prevail, i.e., those prices which actually occur when the individual is in state one or state two in period one (see Arrow (1964)).
The externality does not enter into the budget constraint as individual
A has no control over its effect on his consumption. The first order
conditions for a maximum are
\[ \pi u_1^1 = \lambda p_1 \]  
(3a)
\[ (1 - \pi) u_1^2 = \lambda p_2 \]  
(3b)
\[ p_1 c_1 + p_2 c_2 = k \]  
(3c)
where \( u_1^1 = \partial u(c_1, c_G)/\partial c_1 \) and \( u_1^2 = \partial u(c_2)/\partial c_2 \).

We must now examine the effect of the externality on \( c_1 \) to see
how it affects individual A's insurance purchases. Totally differenti­
atating (3a-c) and solving the resulting equations simultaneously yields
\[ \frac{dc_1}{dc_G} = \frac{-p_2 \pi u_{12}}{p_1 \left[ \frac{p_2}{p_1} \pi u_{11} + \frac{p_1}{p_2} (1 - \pi) u_{11}^2 \right]} \]  
(4)
The sign of the denominator will be negative as it is assumed that
individual A is risk averse. Thus his utility function is strictly
concave \( (u_{11}^1 < 0, u_{11}^2 < 0) \). The sign therefore depends on the cross
partial, \( u_{12} \), the effect of the externality on consumption in state one.
\( c_G \) is a negative externality (diseconomy) and in most cases we may assume
\( u_{12} < 0 \) and the whole expression is thus negative.

---

1 A's indifference curves are assumed to be convex-throughout. Thus
the second order conditions are satisfied. This assumption may not
be valid, for the introduction of the stochastic externality may lead
to nonconvex preferences and indifference curves between states one
and two. See my discussion of nonconvexities in part C of this
chapter and Starrett (1972).

2 This assumption may not be valid in some externality cases.
The introduction of the externality decreases state one consumption and we would expect the individual to attempt to equalize his expected utility in the two states by purchasing insurance against state one's occurrence. Individual A may thus wish to exchange claims to his consumption in state two for consumption in state one, that is, buy insurance against the stochastic externality if state one occurs. The afflicted party has to know the value of $u_{12}^1$ to determine if the expected benefits of insurance for state one are equal to (or greater than) the price of the insurance. The price of insurance will depend (as in the case of an ordinary uncertain event) on the actuarial calculation of the risk. If consumption between states can be exchanged at a constant rate, then the price of insurance, $\alpha$, will equal $dc_2/dc_1$. Individual A will buy insurance if

$$\alpha = \frac{u_{11}^1}{(1-\pi)u_1^2} = \frac{P_1}{P_2} = \frac{1}{1-\pi}.$$ (5)

If the price of insurance is actuarially fair, then the ratio of the probabilities will equal the price of insurance ($\alpha = \pi/(1-\pi)$) and (5) becomes $1 = u_1^1/u_1^2$. If A's marginal rate of substitution between states one and two is decreasing, his consumption bundle will be equalized in both states and he will have full insurance against the

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This result is analogous to conventional utility theory, i.e., in equilibrium, the relative price between the two commodities (here the price of insurance in terms of the consumption in the two states) must equal the individual's marginal rate of substitution between the two goods. We only add the ratio of the probabilities which drop out if the price of insurance is actuarially fair.
stochastic externality. A is thus indifferent to which state occurs.\textsuperscript{1,2}

If the price of insurance is actuarially fair, then the incentive to insure is independent of the probabilities of the events. That is, \( \alpha = 1 \) in this case and \( \pi/1-\pi \) drops out of equation (5). In part C of this chapter, we can no longer utilize this result, as the price of insurance will no longer be independent of the probabilities of the events.

As might be expected, the introduction of an externality into one's expected utility function will not fundamentally alter the provision of insurance. The externality merely complicates the expression if technological information is perfect. In general, if there was full insurance coverage prior to the externality (i.e., premiums are actuarially fair), there will be full coverage after the introduction of the stochastic externality, given that the externality does not affect the probabilities of the events. If the buyers and sellers of insurance have the information necessary to calculate risk and the effect of the externality on one's consumption possibilities in alternative states, contingent markets will tend to operate.

\textsuperscript{1} See Ehrlich and Becker (1972) for further discussion of these points and Arrow (1974) for proofs.

\textsuperscript{2} Note that the conclusion that A is indifferent to the outcome assumes that A has a preference ordering over the stochastic externality. This assumption may be unrealistic if the externality involves the possibility of serious illness or death. But perhaps we should not worry about this problem. People do buy full life insurance and presumably would also purchase for example, botulism insurance.
There are some difficulties with the application of this insurance model to stochastic externalities. First, we must look at the behavioral assumptions implicit in the principal-agent approach. Only the demand side of insurance markets is modelled in the principal-agent relationship. No specific behavioral hypotheses are postulated for the suppliers of insurance except to assume that the agent maximizes his profits by maximizing the expected utility of the principal. Given the identification and actuarial determination of a risky event, agents will instantaneously emerge to maximize the principal's expected utility. But who finds whom? How do agents identify the individuals potentially affected by the event? We must assume that the insurer has perfect technological information for the afflicted and generating parties.

We should also consider who will buy the insurance in the case of a stochastic externality. Clearly, this depends on the specification of prior rights, if they exist. One could ask the "Coase" question: is allocative efficiency dependent on which party buys insurance? Conceivably, we could have a situation analogous to the certainty case in which the afflicted party sells insurance to the generator or the reverse, depending on the rights delimitation. Or one could introduce a third party (the insurance company or a government) which collects premiums from one party and distributes them to the other when the event occurs. The payments would cover different events. Under one arrangement, the generator would receive an insurance payment if the externality did not occur, whereas under the alternative, the afflicted party would receive a payment if the externality did occur. This situation is the uncertainty
analog of the tax-subsidy case, and one would expect that the efficient solution reached does depend on who buys insurance.

Thus far, there is nothing in the formulation of a stochastic externality that effectively differentiates it from other stochastic events covered by optimal insurance contracts. As long as a principal emerges to sell insurance and can determine the actuarial value of the externality, an optimal contract can be written, if rights are delimited. Determining actuarial values requires a sufficient number of observations so that the law of large numbers is effective and risks are then statistically independent. In general, the numbers affected by any given stochastic externality will be relatively small, thus complicating the actuarial computations. But we do observe companies such as Lloyds which write insurance for just about any event. Risk independence is preserved for stochastic externalities as long as they are assumed to be non-collective externalities, i.e., they are not public bads.

Clearly, there are many cases where an externality is stochastic and public; for example, core melt-downs of nuclear power plants and oil spills from supertankers. In these cases, risks to all afflicted parties are not only interdependent, but the events affect a large number of people simultaneously. That is, the risks are too social to write private insurance. A core melt-down of a power plant in a metropolitan area may affect hundreds of thousands of people. No private market is likely to exist in these circumstances. The usual argument at this point is to consider social or government insurance. Whether or not government insurance can lead to efficient and optimal solutions
is a topic of considerable debate which I shall not enter. The point is that the optimal insurance framework may be inappropriate for analyzing many externality cases.

Could individuals reach optimal outcomes given a stochastic externality without purchasing market insurance? One possibility is that individuals engage in self-insurance. Ehrlich and Becker (1972) define self-insurance as actions taken by individuals to reduce the size of the loss, for example, purchasing rubber bumpers for one's automobile to decrease damage when struck by another vehicle. Self-insurance and market insurance tend to be substitutes and thus the individual's choice of which insurance alternative to take depends on the relative prices.¹

If G and A have different methods of self-insurance, then there is no guarantee that the efficiency frontier reached by each party with self-insurance (or a combination of market and self-insurance) is identical.² The differences in self-insurance ability can therefore have an impact on the choice of prior rights and social outcomes. In the botulism case for example, the food firm may be able to employ one individual to prevent all leaky cans from being sold. Similarly, each consumer can avoid the purchase of leaky cans (if he has perfect

¹ Ehrlich and Becker solve for an efficient level of self-insurance and combinations of market and self-insurance.

² This point is analogous to that made by Archibald and Wright (1974) with regard to abatement techniques under ordinary externalities.
technological information in that he knows all leaky cans contain botulism toxin). The abatement techniques are similar, yet society may be better off (in the sense that it can reach a higher frontier) by employing one individual rather than having all consumers check for leaky cans. In addition, the similarities in abatement technique depend on the assumption that technological information is perfect. If information is imperfect, abatement techniques are not identical. Consumers may not know how to distinguish cans which contain botulism from cans which do not. Thus we have the possibility that different distributions of prior rights will lead to different social outcomes depending on self-insurance techniques, although both may be technically efficient in the sense that the insureds' marginal rates of substitution over states equal the self- or market insurance price. This suggests that the party which can abate at lower cost or achieve the highest frontier should bear the liability for the stochastic externality. ¹

I have shown that stochastic externalities do not prevent the operation of contingent markets as long as technological information is perfect. Aside from the difficulties of defining risk, private markets could exist for the stochastic externality cases considered. Market failure is thus unlikely to stem from stochastic externalities. This means that we have still not explained the persistence of externalities in the economy and why certain insurance markets do not exist. I turn now to an examination of information externalities.

¹ See Chapter IV, part C for an elaboration of this point in the context of liability rules.
C. The Operation of Contingent Markets with Information Externalities

This section entails an examination of market failure that arises from information externalities. Recall from section A of this chapter that an information externality may arise whenever the externality (derived from the production or consumption activities of one agent) enters another agent's expected utility function as an argument of the probability of the occurrence of a stochastic externality. Technological information is also assumed to be imperfect in that the afflicted party does not know the "technology" of the generating party that creates the externality. As in section B, I assume that private negotiation between A and G to internalize the externality is unlikely due to the absence of prior rights, and A thus seeks market insurance. Another assumption, appropriate for the cases considered in this section, is that any potential insurer either possesses the same or less technological information than the afflicted party, never more information.

Before presenting my model of an information externality, I would like to note that some of the insurance literature, namely, Arrow (1963, 1968), Pauly (1968, 1974), Akerlof (1970), Ehrlich and Becker (1972), and Helpman and Laffont (1975), have considered the effect of imperfect information on the attainment of competitive insurance equilibria.

\footnote{It is a matter for the legal system whether bargaining made without an assignment of rights is recognized as an enforceable contract. I will not discuss this issue.}
I shall incorporate and apply some of the results of their analyses to my discussion of externalities. The insurance literature identifies two types of effects on insurance markets from imperfect technological information: moral hazard and adverse selection. I shall define these terms then show how information externalities can give rise to market failure from moral hazard and adverse selection.

Moral hazard and adverse selection may arise when the insurers have less technological information (or their information is more imperfect) than the insured. Adverse selection is said to exist when the seller cannot determine or evaluate some of the characteristics of the buyer that affect the probability of the occurrence of states (Pauly, 1974, p. 45). The usual example given is that insurers cannot distinguish between good and bad risk individuals in the present state and thus cannot charge an efficient insurance price related to the specific risks of each group. Moral hazard exists when the insured can engage in activities that alter the probabilities of the uncertain events in response to insurance. Insurance sellers are assumed to be unable to monitor these activities and thus cannot charge premium prices that are functionally related to the insured's activities. If the insurer can determine the relationship between the insured's activities and the probabilities of uncertain events, optimal insurance contracts can be written. An example of moral hazard in insurance markets is negligence that leads to fire when property is insured. In both cases, insurers lack technological information, but in the case of moral hazard, an additional problem emerges in that the probability
of an uncertain event is now dependent on individuals' actions (e.g., their abatement technology). Moral hazard thus involves a situation analogous to my information externality.

I shall now formalize an information externality, then derive some propositions about the operation of markets from the model. I will first assume that both generating and afflicted parties can engage in activities that affect the probability of the occurrence of the stochastic externality. For example, let
\[ \pi_s^A = \pi_s^A(z^A, z^G) \]
where A and G are again the afflicted and generating parties, \( \pi_s^A \) is the probability of state s (a stochastic externality to A) occurring, and \( z^A, z^G \) are activities which both A and G can engage in, which affect the occurrence of the event. In general, we assume \( z^A \neq z^G \).

An externality is present when \( \frac{\partial \pi_s^A}{\partial z^G} \neq 0 \). I also assume that \( \frac{\partial^2 \pi_s^A}{\partial z^G \partial z^A} \neq 0 \), although this assumption is not necessary for the existence of an externality. If state s entails losses for A, then

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1 Another way in which moral hazard can interfere with insurance markets is due to improper or incomplete specification of the activities which give rise to the stochastic event. Divorce insurance is not likely to exist for example, because insurers cannot specify the variables that prevent or lead to divorce. Insurance payment for divorces would have to be made contingent on something other than "trying hard" to make marriage work. This is not a question of information per se, but rather of defining a variable that can be measured.

2 I can complicate the analysis further by assuming that both the probabilities and the utility function are affected by the generating party's activities. See part A of this chapter. This exercise would complicate already unmanageable expressions without adding much in content.
$z^G$ is an external diseconomy if $\frac{\partial \pi^A}{\partial z^G} > 0$ and $\frac{\partial^2 \pi^A}{\partial z^A \partial z^G} < 0$.

A classic example of an information externality is immunization against epidemic disease. State $s$ is the disease (e.g., the flu) which is a random event to a given population. The occurrence of $s$ to any individual $A$ depends both upon his own immunization against the flu and the immunizations of others. $\frac{\partial \pi^A}{\partial z^G}$ and $\frac{\partial \pi^A}{\partial z^A}$ are both assumed to be negative in this case, but the total effect depends on the cross partials between $z^A$ and $z^G$.

Note that risks may no longer be statistically independent in this case. Risk independence is clearly lost when the $\pi^i$ for all $i$ individuals depends on everyone's level or extent of immunization. In a sense, I have slipped public goods into this analysis, but this is not necessary. As soon as $\pi^A(z^A,z^G)$ occurs for any $A, G$, statistical independence is lost, whether the externality is collective or not. If risks are not independent, whether or not any insurance policies are offered by insurers depends on the information they have about the $\pi^i(z^i)$ functions. If insurers have perfect information, actuarial values can be calculated, taking into account the interdependencies. If insurers have imperfect information about $\pi^i(z^i)$, there exist two (at least) possibilities. First, insurers may perceive the existence of risk dependencies, but do not know how the $z^i$ affect $\pi^i$. In this case, one would not expect profit maximizing insurers to offer any premiums for sale. Insurers may not however be aware that probability is dependent upon $z^i$. They will estimate risks and charge premium prices that do not, except by chance, correspond to the optimum. There
is also the possibility that insurers will "learn" of the risk after insurance payments to a number of individuals are made.

Non-existence of an equilibrium is thus likely. A zero profit condition for insurers can be simply that \( \sum_i \pi_i X_i = \sum_i P_i \), where \( X_i \) is the insurance payment made in state \( s \) to individual \( i \) (for all \( i \) and \( s \)), and \( P_i \) is the premium charged (both in terms of income). If insurers assume that all individuals are identical, all \( \pi_i \) are affected by \( z_i \), and insurers charge a premium that is less than the expected value of losses, then individuals will buy excessive amounts of insurance. The probabilities of all states will be affected and insurers will make losses, or \( \sum_i \pi_i X_i > \sum_i P_i \). If insurers charge a premium price in excess of expected values, and the marginal cost of the individuals' \( z_i \) activities are less than the premium, no insurance will be purchased and thus no equilibrium will exist. If \( z_i \) "costs" more than the premium, some insurance may be purchased, but then \( \sum_i \pi_i X_i < \sum_i P_i \), excess profits will be made and the premium price must decrease.

If probabilities are dependent on activities in some, but not all states, equilibrium may continue to be non-existent. If individuals are identical, and the states which correspond to activity-dependent probabilities are distinguishable from other states, insurers may be able to write premiums such that \( \sum_i \pi_i X_i = \sum_i P_i \). This may entail some loading in those states where probabilities are independent and individuals have no options of using \( z_i \) (e.g., no abatement techniques). If individuals are not identical, adverse selection may arise and equilibria may not exist. One other possibility with non-identical individuals is that
only a few individuals are capable of influencing probability. If the event affects large numbers of individuals, the activities may cancel out or become insignificant with aggregation. That is, the impact of the activities that generate externalities is too small to affect the probabilities.

Let us now assume that insurers can determine risks and see what happens to expected utility maximization and insurance with an information externality. The information externality can be introduced in several ways. I will illustrate what I think is the simplest case. There are two states; 1 and 2, with probabilities $\pi$ and $(1 - \pi)$. We will maximize the expected utility of a party afflicted by the externality. All A's are therefore identical. A's utility functions for each state are assumed to be concave. Let us first define the conditions for A to maximize his expected utility, then we shall introduce an insurer. Using notation similar to the case of a stochastic externality, the problem is to maximize

$$U^* = \pi(c_1, z)u(c_1) + [1 - \pi(c_1, z)]u(c_2)$$

subject to

$$p_1 c_1 + p_2 c_2 = k,$$

where $p_1, p_2$ are again contingency prices, and $k$ is wealth minus consumption in period zero. $z$ is the externality and is a function of the generating party's consumption in state one; $z = z(c_1)$. A cannot control $z$. $z$ could also be an output of a firm which only occurs in state one.
I assume that the probabilities of states one and two are dependent on the activities of both the afflicted and generating parties, and that A's activities are what he could consume in state one. \( \frac{\partial \pi}{\partial c_1} \) is assumed to be negative and \( \frac{\partial \pi}{\partial z} \) positive. That is, \( c_1 \) decreases the probability of state one occurring, while \( z \) increases the probability. State one affects individual A adversely, and \( z \) is therefore an external diseconomy. An example (if \( z \) is an output in state one) is asbestos-inducing cancer. In state one, A contracts cancer, in state two he does not. He can engage in activities in state one (e.g., wearing a respirator, installing air filters in his home and staying indoors) that decrease the probability of state one. Simultaneously, G can engage in activities that increase the probability and thus generate an externality (e.g., not having emission controls on asbestos fibres). A stochastic externality also exists in this example, but for simplicity, we will not add \( z \) (or \( c_G \)) to A's utility function for state one.

The first order conditions for a maximum are

\[
\begin{align*}
\pi_1 \left[ u(c_1) - u(c_2) \right] &+ \pi(c_1, z)u_1 + \lambda p_1 = 0 \quad (8a) \\
\left[ 1 - \pi(c_1, z) \right] u_2 + \lambda p_2 & = 0 \quad (8b) \\
p_1 c_1 + p_2 c_2 - k & = 0 \quad (8c)
\end{align*}
\]

where \( \pi_1 = \frac{\partial \pi(c_1, z)}{\partial c_1}, u_1 = \frac{\partial u}{\partial c_1}, \) and \( u_2 = \frac{\partial u}{\partial c_2} \).

In equilibrium

\[
\frac{\pi_1 \left[ u(c_1) - u(c_2) \right] + \pi(c_1, z)u_1}{(1 - \pi(c_1, z))u_2} = \frac{p_1}{p_2} \quad (9)
\]
Equation (9) can be interpreted as requiring the equality of the marginal gain from decreasing the probability and the marginal cost of the purchase of $c_1$ (given $z$) in terms of decreased consumption in state two. Individual A will be in equilibrium, but this will not be optimal because he has no control over $z$. Equation (9) thus indicates A's best attainable point independent of G. But note that A cannot even evaluate this point unless he has technological information about G's activity, $z$. If we assume he has this information for the moment, let us consider how the dependency of the probability of state one on A's and G's activities affects the expected utility maximum.

Consider a sufficient condition for a maximum,

$$
\pi_1 u_1 c_1 + \pi_2 u_2 c_2 + \pi_{12} u_{12} > 0
$$

The expression is somewhat complex and signing it is not an easy task. A number of assumptions are necessary and even with these, no guarantee exists that the condition will be met. Even if we assume $\pi_{11} < 0$, $\pi_{22} < 0$, $\pi_{1z} < 0$, and $\pi_{1} < 0$, we cannot tell if (10) is negative, as the terms $-\pi_{11} u(c_1)$, $-\pi_{1z} u(c_1) dz[u(c_2)]$ and $-\pi_{12} u_{12} dc_{12}$ will be positive. If $\pi_{11} < 0$, the same problem occurs. In addition, we cannot be sure of the sign of $\pi_{1z}$. If $\pi_{1z} > 0$ over some ranges, then again, (10) may not be negative.

Also note that we do not even know if A's expected utility ($U^*$) will be quasi-concave. A's concave utility function in state one must be
multiplied by the probability function \( \pi(c_1, z) \). Quasi-concavity of
\( U^* \) requires \( \{ x \mid U^*(x) \geq c \} \) is convex for all \( c > 0 \). Whether or
not this condition is satisfied when we multiply A's utility functions
by probability functions is not clear.\(^1\) In addition, we may have some
reason to expect that the probability functions are nonconcave. As
the generating party increases \( z \), \( c_1 \) becomes less and less effective
in decreasing \( \pi \). Individual A cannot control \( z \), but he can alter \( c_1 \).
In particular, he may be able to increase his purchase of market
insurance (if available) and simply stop consuming \( c_1 \) at some level
of \( z \).

The question is, should we worry about the possible non-quasi-
concavity of equation (6)? Is quasi-concavity of the expected utility
function necessary for the existence of an equilibrium? We have now
introduced the possibility that individual A's demand curves for con-
tingent commodities will be discontinuous. Arrow (1964) argues that

\(^1\)

Even if we assume that the probability functions are strictly concave
in \( c_1 \) and \( z \), we cannot guarantee that \( U^* \) is concave (but it may still
be quasi-concave). For simplicity, let \( U^*(c) = \pi(c)u(c) \). Let us
ignore the externality and state two. Can we then sign the second
differential of \( U^* \)?

\[
\begin{align*}
\text{d}U^* &= \pi_1(c)u(c)dc + \pi(c)u_1(c)dc = 0 \\
\text{d}^2U^* &= \pi_{11}(c)u(c)dc + 2\pi_1(c)u_1(c)dc + \pi(c)u_{11}(c)dc \geq 0.
\end{align*}
\]

The first and third terms are negative from our strict concavity
assumptions for the probability and utility functions. The second
term is positive. Thus \( U^*_{11} \) cannot be signed without additional
information about the relative size of the terms.
quasi-concavity of expected utility functions is not necessary for the existence of competitive equilibria if there are a large number of individuals, each with small incomes. Helpman and Laffont (1975) show, on the other hand, with an example of an expected utility function that is not quasi-concave, that no competitive equilibria can be attained even if they aggregate over large numbers of consumers. In their model, individuals either choose full insurance (and the level of activity $c_1$ goes to zero), or they purchase negative insurance. In both cases, the insurance companies incur losses because the probability of the event has changed and their premium price has not adjusted to the new risk situation. I cannot reconcile these two conflicting arguments at this point, but want to merely point out the possibility of non-existence of equilibria if expected utility functions are not quasi-concave.

We now ask if individual A can purchase market insurance. Assuming individual A knows the effect of $z$ on $\pi$, he will choose a utility maximizing premium given (9) and the dependence of the premium and $c_1$ on the amount of insurance purchased. Expected utility is now defined over consumption and insurance, or

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1 Arrow's argument is based on Rothenberg (1960). He suggests that, with aggregation, all the "holes" or discontinuities in demand functions are filled if individuals are different. If individuals are identical, equilibrium is still attained over all prices, because individuals are indifferent between the boundaries of the discontinuity and the market clears. Also see Rothschild and Stiglitz (1975).

2 See Pauly (1974) for an elaboration of this model (without externalities). This is the second part of a two-stage maximization. Individual A first chooses the $c_1$ that satisfies equation (9), then determines the amount of insurance he will buy ($X$) by maximizing his expected utility given $c_1$ and the value of the premium.
where \( P \) is the total premium paid for \( X \) dollar's worth of insurance, \( L \) is the loss which occurs only in state one, and \( c_1 \) and \( P \) are dependent on \( X \). The first order condition for a maximum of (11) is

\[
\frac{\partial P}{\partial X} \left[ -\frac{\partial (c_1,z)}{\partial c_1} u'(1) + \left[ 1 - \frac{\partial (c_1,z)}{\partial c_1} u'(2) \right] \right] = -\frac{\partial (c_1,z)}{\partial c_1} u'(1)
\]

(12)

Dropping the price ratio in (9) and substituting for \( \frac{\partial \pi}{\partial c_1} \) yields the optimal premium-to-benefit ratio, or insurance price.

\[
\frac{\partial P}{\partial X} = -\frac{\partial (c_1,z)}{\partial c_1} u'(1) \frac{1 - \frac{\partial (c_1,z)}{\partial c_1} u'(2)}{1 - \frac{\partial (c_1,z)}{\partial c_1} u'(2)}.
\]

(13)

I assume that the insurance market is perfectly competitive and insurers thus satisfy the zero profit condition given by

\[
\sum_i \pi_i x_i = P_i
\]

(14)

where \( i \) is all individuals affected by the externality.\(^2\)

If insurers could observe \( c_1 \) and \( z \), for all \( A \) individuals, the premium would vary with \( \pi \) and an "optimal" amount of insurance could be sold. That is, each insurer would set his premium price equal to the solution to (13). Again, this is not a strict optimum because

\[1\] \( u(1) = u(c_1 - P - L - X) \) and \( u(2) = u(c_2 - P) \).

\[2\] Strictly, (14) should also be summed over all states.
neither A nor the insurer can affect z. It is just an equilibrium, given z. Notice however the informational requirements on the insurer. He must be able to solve (13), which requires technological information not only about the activities of A, but also those of G as well. Insurers must therefore be able to identify the Gs and ascertain the way in which z enters the probability functions of A. We can then ask if the Gs will have any incentive to reveal information to insurers. This is doubtful unless they are required to provide information by an assignment of rights and liability. Notice also that even if insurers can evaluate $\pi(c_1, z)$, acquiring this information is costly. I have not explicitly introduced these transaction costs into the model, but I could assume that this results in loading of insurance premium prices. We know from Arrow (1974) that loading may decrease the extent of insurance coverage in any state.

If an insurer cannot observe $\pi(c_1, z)$ and therefore cannot base insurance prices on the activities' effects on probability, moral hazard exists. That is, if the insurer does not vary the premium price with changes in the level of $c_1$ and z, he will not charge a price equal to the solution to (13). Pauly (1974) shows how the competitive equilibrium will vary from the "optimal" outcome expressed by (13). The argument is that any one insurer will be unable to determine the total amount of insurance each individual affected by the externality purchases. Insurers will only know the amount of insurance

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1 See Chapter IV for discussion of this incentives problem.
bought from their own firm and not the coverage purchased from other insurers by the A's. Therefore, each insurer cannot adjust the premium price to the amount of insurance purchased by each individual. Expected losses increase with the amount of insurance purchased, i.e., the greater the amount of insurance A purchases, the smaller will be his level of preventive activity, c₁, and thus, the larger the probability of the stochastic externality. z will probably not change in response to insurance on A, as G's are assumed to be maximizing their utility (or profits) independent of A. Insurers will thus be under-pricing their premiums. If insurance buyers have perfect market information about insurance prices, they will perceive that they face a horizontal supply curve and insurers must therefore charge one price for all units of insurance. ∂P/∂X then becomes p, one price for all units of insurance, for all individuals. The equilibrium p must satisfy the zero profit condition (14), or p = \( \frac{\pi}{X} \sum_{i} X_i \). The \( X_i \) cancel as they are the same for all individuals for any given p. The condition then becomes \( p = \pi \). \( \pi \) is clearly less than the premium schedule given by (13). Thus, there tends to be an overproduction of insurance relative to the "optimum", and an underuse of activity c₁.

If insurers cannot determine \( \pi(c_1, z) \), but can observe A's total purchase of insurance, Pauly (1974) showed that the "optimal" schedule of premiums could be found by maximizing the expected utility of A subject to the insurer's zero profit condition. If all individuals are identical, they will all purchase the same amounts of insurance
given a price schedule. But the introduction of z may imply that all individuals are not identical. First, although state one may be defined for all individuals, z may only enter the utility functions of some of these individuals. For "optimality", insurers should be able to distinguish these individuals from those whom z does not affect. The total amount of insurance purchased by afflicted parties will be different for a given premium schedule, P(X), then the insurance purchased by those unaffected by z. In particular, we would expect more insurance purchased by afflicted parties, as \( \frac{dc_1}{dz} \), the effect of the externality on A's activity, is negative. \( \pi^A \) is therefore higher for A's than the \( \pi \) for all unaffected parties. We now have an adverse selection problem. That is, insurers must not only be able to observe total insurance purchases, they must also be able to distinguish between risk classes of individuals. Insurers may try to compete for the low risk group, but will not be able to do so unless they have the information to distinguish between risk classes. If they have this information, it is possible that the zero-profit condition on all contracts will be violated. If insurers pool their risks and charge one price (when individuals vary), an inefficient outcome is obtained.

If individuals are different, whether insurance (if sold at all) is under or over-provided relative to the "optimum" is difficult to determine. The moral hazard aspect of the problem would lead to over-insurance, whereas the adverse selection would lead to under-insurance. One suspects that no equilibrium will exist. If an equilibrium exists,
it is not likely to be efficient. Unless all insurers have identical information about the $\pi = \pi(c_1, z)$ for all individuals and can perfectly discriminate in premium pricing with respect to risk (of the afflicted versus the non-afflicted parties), either excessive amounts of insurance will be sold with the non-afflicted in effect subsidizing the afflicted (as all pay the same premium), or no insurance will be sold as all firms would make losses.

One could then ask the question: if the government wanted to achieve a Pareto optimal level of externality by imposing for example, liability laws or through taxation and subsidy, what would this solution look like in the case of an information externality?\(^1\) I shall show that this Pareto optimal solution is rather peculiar.

If we maximize the afflicted party's expected utility subject to keeping the generating party's expected utility constant, a Pareto optimal allocation between the two parties can be determined.\(^2\) For simplicity, I assume that only A's probabilities are dependent on his and G's activities and there are only two states. The problem is thus to maximize the Lagrangian

\[^1\] Alternatively, we could view this as an exercise in determining the optimal bargaining solution between A and G. But I find the government question much more realistic. Private bargaining requires that both parties know the effects of A's and G's activities on $\pi$. While it is likely that they may know their own activity's effect, there is no way they will a priori be able to determine the effects of the other party's activities. Given the possible mendacity of each party (as both can gain by revealing false information), bargaining is a remote possibility, or if carried out, likely to be inefficient.

\[^2\] Again, this is subject to the difficulties imposed by possible non-convexities.
\[ V^* = \pi[c^1_1, z(c^G_1)] u^A(c^A_1) + \left[1 - \pi[c^A_1, z(c^G_1)]\right] u^A(c^A_2) + \lambda[y u^G(c^G_1) + (1 - \gamma) u^G(c^G_2) - \bar{u}^G] + \mu_1(c^A_1 + c^G_1 - \bar{c}_1) + \mu_2(c^A_2 + c^G_2 - \bar{c}_2). \] 

Note that in this case, \( z = z(c^G_1) \). First order conditions are that

\[ \begin{align*}
\pi_1[u^A(c^A_1) - u^A(c^A_2)] + \pi_1[c^A_1, z(c^G_1)] u^A_{c^A_1} + \mu_1 &= 0 \quad (16a) \\
\left[1 - \pi_1][c^A_1, z(c^G_1)] u^A_{c^A_2} + \mu_2 &= 0 \quad (16b) \\
z_1^* \pi_2[u^A(c^A_1) - u^A(c^A_2)] + \lambda(yu^G_{c^A_1} + \mu_1 &= 0 \quad (16c) \\
\lambda[(1 - \gamma)u^G_{c^A_2} + \mu_2 &= 0 \quad (16d) 
\end{align*} \]

where \( u^A_{c^A_1} = \partial u^A/\partial c^A_1 \) and so on. Eliminating the multipliers yields the unwieldy expression

\[ \frac{\pi_1 - z_1 \pi_2[u^A(c^A_1) - u^A(c^A_2)] + \pi_1[c^A_1, z(c^G_1)] u^A_{c^A_1}}{(1 - \pi_1)[c^A_1, z(c^G_1)] u^A_{c^A_2} + (1 - \pi_1)[c^A_1, z(c^G_1)] u^A_{c^A_2} + (1 - \gamma) u^G_{c^A_2}} = \frac{\gamma u^G_{c^A_1}}{\gamma u^G_{c^A_1}}. \] 

Note that this solution is very different from the Pareto optimality conditions with ordinary commodities. The solution is "Pareto optimal" not with respect to individual's revealed preferences, but with respect to the technological information about each
party's functions. As noted in section A, technological information is necessary for optimality when we have externalities. The information demand on the government would thus be enormous, and Pareto optimal outcomes thus unlikely. Is there any role for government with information externalities?

There are two basic options for government: providing social insurance or imposing laws or regulations on the operation of private insurance markets.\(^1\) Government can provide compulsory insurance in an attempt to reduce the possible over-insurance resulting from imperfect information. Individuals would only be allowed to purchase fixed amounts of insurance. Whether the amount of insurance sold and premium price charged correspond to the "optimum" depends on the government's information. If the government can calculate a premium schedule that satisfies the condition

\[
\frac{\partial P}{\partial X} = \pi + X \frac{\partial \pi}{\partial X} = \frac{-\pi(c_1,z)u'(1) - \frac{\partial C_1}{\partial X} (1-\pi)(c_1,z)u'(2)}{-\pi(c_1,z)u'(1) + (1-\pi)(c_1,z)u'(2)} \tag{18}
\]

the optimal number of premiums, \(X^*\), can be sold.\(^2\) If the government can also regulate the private insurance industry to sell \(X^*\) and charge

\(^1\) There is a third option: the imposition of a legal liability system that assigns rights (contingent) after the event occurs. This is the subject of Chapter IV.

\(^2\) This expression is derived from the assumption that the government can observe an individual's response to an increment in insurance. See Pauly (1974, p. 49). It is also assumed that individuals are identical. The notation is the same as in equation (12).
\(3F/3x\) that satisfies (18). The government could also require by law that individuals reveal to insurers the total amount of insurance purchased. All firms would then charge the same premium for any incremental coverage individuals may seek over the optimum (due to a decrease in their \(c_i\) activities). How this law would be enforced is an interesting question that cannot be answered in this thesis.

If individuals are not identical and thus the information externality does not affect all people equally, government insurance can lead to some improvement over no insurance (possibly). Because governments can pool risks, insurance may be offered for events that would remain uninsured in private markets due to small numbers or interdependent risk. Adverse selection will be eliminated by this policy, but it will be replaced by a transfer of income from good risk to bad risk individuals. Whether or not social improvements result depends upon the relative numbers of afflicted versus non-afflicted parties. That is, with compulsory insurance, afflicted parties (if sufficiently large in number), may be imposing a burden on non-afflicted parties in the form of higher premiums. It is not then clear whether any social improvement takes place, as non-afflicted parties' welfare decreases and the externality may still be non-optimally insured.

I will briefly summarize the points derived from the model of information externalities. (1) Perfectly competitive insurance markets may not arise because risks are no longer statistically independent with information externalities. (2) If individual's expected utility functions are not quasi-concave, insurance equilibria
may not exist. (3) Even if competitive insurance markets and equilibria exist, the competitive market solution may lead to non-optimal (in the revised context) premium prices for insurance if insurers cannot monitor afflicted and generating parties' activities.

(4) Technological information over all A and G parties is necessary for "Pareto optimal" allocations with information externalities.

I reiterate that one must be very pessimistic about the possibility of reaching an optimal allocation of resources through private markets when externalities arise from imperfect information. The amount of information required to obtain an optimum in any externality situation is substantial and complex. Given costs of acquiring information, few, if any, insurance markets will operate. Government insurance or regulated monopolies will not necessarily achieve first best optima, but may lead to some social improvement. There is an argument for government control when information is imperfect. If private markets do not have perfect information, perfect competition is incompatible with efficient equilibria (and may lead to non-existence). If perfect information exists, the type of externalities described in this chapter will not persist. Therefore, if one is concerned about internalizing externalities, albeit imperfectly, government regulation or government provision of information is necessary. We turn now to a specific nonmarket means of dealing with externalities arising from imperfect information: liability laws and legal rules.
IV. INSTITUTIONAL RESPONSE TO IMPERFECT INFORMATION: LIABILITY LAWS AND LEGAL RULES

A. Introduction

We have seen from the analysis in Chapter III that private insurance markets may fail, or operate inefficiently when stochastic and information externalities are present. Government may regulate individuals' activities or operate social insurance markets, but there is no guarantee that efficiency or optimality results from government control. One problem with either social or private insurance was the determination \textit{ex ante} of the risk of any event involving an externality due to the small numbers of agents involved and interdependency of probabilities. A second problem was that prior rights may not be assigned to specific agents in the case of a stochastic or information externality. In this chapter, I will evaluate an alternative institutional response to externalities arising from imperfect information: the role of the legal system in the assignment of rights and the effect of rights on resource allocation given stochastic and information externalities. I assume that the government has created a legal system comprised of law-making bodies (a parliament, legislature, or regulatory agencies), a set of common and statutory laws, a court system (judges, juries, and lawyers), and methods of enforcing all laws and regulations. The legal system has the task of delimiting prior and contingent rights and enforcing compliance with the powers these rights entail.
If prior rights are defined over stochastic externalities, we have a situation as depicted by the model in Chapter III, part B. That is, if it is known which party is liable in any situation, the private market's problem is simply the determination of the actuarial value of the stochastic externality. Insurance markets could function efficiently in this case. Recall however that the "efficient" solutions obtained in part B (and part C as well) are relative to the assignment of rights. Efficiency frontiers for different assignments of rights will not in general be identical. Also note that the efficient solutions were not optimal as neither the insurer nor the afflicted party could affect the generating party's behavior. One would expect in cases where legal jurisdiction was clearly defined, that prior rights would cover stochastic externalities, as the information requirements are small relative to other externality cases. Given the assignment of prior rights for stochastic externalities, the legal system then has a choice over the powers these rights convey. Prior rights will not only identify the liable party but also set forth the rules and limits of compensation under the legal system if the event occurs. Both legal rules for compensation and private insurance can thus provide state-dependent payments. Whether or not individuals buy private insurance depends upon the relative costs of insurance (premium/benefit ratio) and enforcement of one's rights (litigation fees, if necessary). Private insurance markets may still arise (and be necessary) if the prior rights favour the generating party and the afflicted party has no legal recourse to compensation.
Legal rules which specify the level and allocation of compensation given a stochastic or information externality will be called liability rules. An example of a liability rule applicable to prior rights is strict liability. The party with the rights will be compensated for all lost income by the party without the rights when the externality occurs. This is therefore an implicit insurance policy.\(^1\) The compensation is generally awarded after the legal system (through the courts) has established that the event has occurred and the liable party (the defendant) was indeed responsible for the event. The legal system will also specify which party has the burden of proof for showing that damage has occurred. It is generally assumed that the liable party (the one without the prior rights) has the burden of proof; i.e., he must show that he was not responsible for the event and damage to avoid paying compensation. Courts may also specify who pays the legal and court fees in the litigation procedure.\(^2\)

One important question which cannot be fully answered in this thesis, is, what criteria should the legal system use to determine the assignation of prior rights? In Chapter II, I argued that the assignment of prior rights affected not only the distribution of income

\(^1\) There may also be some taxpayer subsidy to the party with the rights to the extent that legal costs are not covered by the liable party's compensation.

\(^2\) This liability rule may clearly be non-optimal, as the party without the rights now bears all the risk and additional insurance may thus be necessary. See part C of this chapter for an analysis of the relative efficiency of alternative liability rules.
between generating and afflicted parties, but also the relative prices of commodities. The legal system thus cannot assign rights without affecting resource allocation. It is somewhat unrealistic to assume that the legal system can compute general equilibrium solutions under alternative rights assignments. But, clearly, any decision made with respect to rights assignments will have effects that should in theory be evaluated.¹ Equity may also be an important consideration in rights determination. Ideally, legal decision-makers would have a ranking of individuals (social welfare function) to evaluate alternative schemes of rights.

Arguments which imply that the initial determination of rights does not affect the equilibrium position attained under social decision-making are untenable. Buchanan and Tullock (1962) pp. 46,48) argue for example, that rights must be delimited before they consider problems of individual constitutional choice, but "the 'efficiency' or 'inefficiency' in the manner of defining human and property rights affects only the costs of organizing joint activity (externalities), not the possibility of attaining a position of final equilibrium". What Buchanan and Tullock never make clear is that choice of rights and the final outcome are interdependent. One cannot assume rights exist, then ignore their effects. It is valid to argue that rights affect costs of decision-making, but one should then go on to say that different sets of rights

¹ When I consider alternative liability rules in section B of this chapter, all general equilibrium effects will be ignored. As will be seen, partial equilibrium cases are themselves quite complex.
lead to different costs, which in turn imply the possibility of attaining different equilibria or of not attaining an equilibrium at all.

I will very briefly sketch some of the methods which might be used by the legal system to determine rights and the problems associated with these approaches. There are two basic methods of determining prior rights. The first is by government legislation, either through a parliamentary body or by a regulatory agency. If a parliament determines rights, its decision-making should in theory reflect some explicit or implicit social welfare function consistent with the preferences of a majority of voters. Rights assignment would then take into account to some extent both equity and general equilibrium effects. We would not however expect that government decisions will represent a social optimum for the following reasons. First, although we can impose Bergson-Samuelson social welfare functions on decision-makers, we cannot generate an Arrow social welfare function from a minimum set of assumptions about individual preferences. Secondly, we have no predictive model of government decision-making, whether by a parliament or regulatory agency. Thirdly, even if a social welfare function exists, we must assume that legislators or civil servants are knowledgeable about all aspects of the stochastic externality and its effects. Those individuals affected by the externality will of course have the most information. The rights assignment made is

These methods also apply to the determination of contingent rights. But with contingent rights, the issues are even more complex as we shall see in part C of this chapter.
therefore likely to depend on the afflicted and generating parties' relative bargaining (lobbying) power with the government. These relative lobbying strengths, one suspects, will be heavily influenced by the parties' income level. Finally, legislative bodies tend to enact legislation slowly (due to both government inertia and the time needed to collect information). Lags between the recognition of a stochastic externality and determination of rights will thus exist.¹

The second and most prevalent method of determining prior rights is through the common law and judicial system. In the determination of prior rights by the courts, the stochastic externality must first affect at least one party who brings a case against the generating party.² If no prior rights existed previously for the particular event, the court must then determine liability for the externality.

¹ An example of legislative assignment of rights is discussed by Samuels (1971). Owners of cedar trees are held liable for a rust that periodically damages apple trees. The rust starts on the red cedars but does not damage them. The externality arises because the rust occasionally spreads to apple trees in the vicinity. Apple tree owners thus have been awarded the rights in the event of a rust epidemic. It is interesting to note that apple tree owners were not awarded the right to receive compensation for their losses. In lieu of compensation, cedar tree owners were required to destroy all their trees whenever the disease appeared in one tree (even unaffected trees) and thus forego the potential logging revenues from the trees. The effect of this distribution of rights certainly has questionable efficiency properties.

² Notice that the determination of rights by the judicial system places the burden of litigation on the afflicted party because the generating party has the de facto rights.
Henceforth, all identical stochastic externalities are covered by that prior right. Again, we can ask what criteria govern the determination of rights. In civil cases, the law of torts covers liability (and hence, rights) determination. It is clear that in many cases, tort law advocates assignments totally unrelated to economic efficiency.¹

One criterion used to determine liability in the United States is the Hand formula (see Posner (1972), pp. 69-70). In terms of a stochastic and information externality, this formula would hold the generator liable for the damage caused by the externality if the damage, multiplied by the probability of the externality occurring, exceeds the cost of the precautions the generator might have taken to avoid the event. In other words, the expected value of the event is compared to the cost of preventive activity. The Hand formula will not lead to efficient levels of the externality if afflicted parties can also engage in activities that reduce the probability of the event. The formula thus acts as a disincentive for afflicted parties to engage in preventive activity. Other examples of legal criteria are the doctrines of contributory and comparative negligence. These doctrines cover cases where both parties can affect the occurrence of an externality. Contributory negligence states that the afflicted party will not be awarded the rights (and ability to recover his damages) if he could have prevented the event at a cost lower than the generating party's preventive costs. Note that this rule acts as a negative incentive on generating parties'¹

¹ See Posner (1972) for more extensive discussion of the relationship between civil law and procedure and economic efficiency.
preventive activities.\textsuperscript{1} Comparative negligence reduces the afflicted party's claims to damages by the percentage that his own activities (or lack of activities) contributed to the event. This rule may also lead to inefficiency in that it may lead to excessive total preventive activities (both parties overinvest in prevention).

Rights decisions can be made in two ways in the judicial system: by judges or juries. In either case, the evidence and arguments presented by the plaintiff's and defendant's lawyers will have an important effect on the decision reached. The legal market affects both the litigation of externality cases and the court's decision on the assignment of rights. We therefore would like a model of the supply of and demand for lawyers and legal services. I will now briefly examine some of the issues associated with the market for legal services.\textsuperscript{2}

One's demand for legal services is a derived demand. What an individual involved in any stochastic or information externality wants is an assignment of rights and liability through the legal system. The demand for rights is basically a demand for a nonmarket allocation due to the failure of private insurance markets. But what we now have

\textsuperscript{1} See sections B and C of this chapter for discussion of possible legal rules (due care standards) that may reduce these negative incentives.

\textsuperscript{2} One should note the similarity between the markets for legal services and for medical care. See Arrow (1963) for an analysis of medical care markets.
is a nonmarket allocation system (rights and liability determination) that is still dependent to some extent on the operation of a private risk-bearing market (legal services). The efficacy of the nonmarket system is thus dependent upon the operation of legal markets. In other that small claims cases, lawyers and legal services are necessary for adjudication. Whether one is successful in obtaining rights and liability favourable to himself is in part a function of the skill and quality of the legal services. The individual also faces uncertainty in the adjudication process. First, he is uncertain if he will win his case. Secondly, he is uncertain about the quality of the legal services which cannot be evaluated prior to the trial or legal negotiations. Thirdly, he is uncertain, even if he wins the case, what the extent of the award will be. The demand for legal service will be irregular and unpredictable as it depends upon the occurrence of a stochastic externality (or other random event). Thus the demand for legal services derives from the lack of insurance markets when externalities exist, and the legal market becomes a market for bearing risk.

Due to its supply characteristics, the fee structure, and prescribed types of civil suits, the legal services market tends to fail in its risk-bearing function. Entry is restricted in the legal services market by licensing, which is in turn restricted by educational requirements. Licensing and education act to a certain extent as signals for the productivity and quality of the service, but the signals are not perfect. Because the productive activity comprises the good sold on the market, the buyer cannot fully determine the value of the output
prior to the completion of the service and final outcome in court. The value of the legal service would thus be an expected value; the amount of compensation awarded times the probability of winning the case. To maximize his utility, the individual would then set the expected value of litigation equal to the cost of legal services (at the margin). This strategy would lead to the efficient operation of legal markets given a zero total profits condition for suppliers of legal services.

The legal market does not however operate efficiently. First, even if individuals did have enough information to compute expected values, a maximum may not be achieved due to the lumpiness of legal fee schedules. Legal fees are based on the definition of the service provided (e.g., \$X per letter), the time involved in case preparation, and the seniority of the lawyer (a signal for his quality). The client will not face a marginal schedule of payments, but discontinuous amounts of service. Fees are also not set competitively, but determined by the licensing body (bar associations). As the licensing body also controls entry of suppliers into the market, the fees are likely to include monopoly rents to the lawyers (analogous to medical service fees). Like medical care, legal services are more realistically defined

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1 The assumption that individuals can compute expected values is questionable. Not only are probabilities difficult to compute because they are so case specific, the compensation payments themselves are subject to (somewhat random) variation. That is, the individual may seek \$X in damages, but only be awarded \$(X - Y).
in terms of total episodes (the litigation process). One could alternatively handle the optimal provision of legal service in a manner analogous to the principal-agent relationship in insurance markets. The legal firm would determine the optimal fee schedule by maximizing the expected utility of its clients subject to a zero profit constraint. The legal system would thus bear the risk of the uncertain litigation and charge premium prices for this service.

Again, the legal system does not operate in this manner. Fees are not only unrelated to the probability of the outcome of the case, but lawyers are prohibited from seeking clients on the basis of their ability to win cases. The buyer must seek a lawyer and bear the risks of the litigation himself. Retaining a lawyer thus becomes analogous to taking a gamble and one would expect different individuals to vary in their demand for legal services according to their attitude toward risk.

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1 Lawyers acting as entrepreneurs (termed fomenting) is proscribed because the legal profession believes this would lead to excessive amounts of petty litigation which would overburden the court system and thus increase costs the taxpayer must bear (increased judges' salaries, new capital expenditures on courtrooms, etc.).

2 Casual empiricism suggests that individuals display decreasing relative risk aversion over some range of their expected utility function in their demand for legal services in cases of stochastic and information externalities. This observation (or assumption) combined with the lumpiness and monopolistic elements of legal fees suggests that one would tend to see more litigation in events affecting relatively higher income individuals. If individuals are risk averse in general, one would expect that few stochastic and information externality cases would be litigated and the de facto rights assignment will reflect the status quo.
Many legal decisions are made however in out-of-court settlements. Posner (1972, p. 337) notes for example in the automobile accident field, 95% of all legal cases are settled by the affected parties before they reach the courts. These settlements do not establish rights. This means that each time the stochastic externality occurs a new round of litigation begins. For example, the thalidomide cases in Europe and the United States were all settled out of court. The rights were not assigned explicitly to the deformed children and thus no uniform standard of compensation was established. This system not only tends to be inequitable, but is also costly in terms of legal services required. Thus, individuals may not obtain an assignment of rights with litigation.

One legal mechanism exists in the United States which enables individuals to decrease their risk through pooling is the class action suit. In cases where the damages to any one individual are quite small, yet many people are affected by the event and total damage is thus large, one individual can bring suit on behalf of all afflicted parties. In class action suits, legal fees can be based on the total award. Thus there are no negative incentives against litigation and the fee structure combined with risk pooling would tend to lead to an improvement in resource allocation with class action suits. ¹

There may also be a tendency in all cases which are litigated to preserve the status quo distribution of rights. This occurs because

¹ Class action suits are currently rare in Canada.
of the nature of legal decision-making; established common and statutory laws set the precedent for many new decisions. The problem with this approach is that events (or technologies) have changed and it is no longer clear that the principles established by existing laws are applicable to the determination of new sets of prior and contingent rights. Note also that the argument that status quo rights represent the preferences of individuals is not valid unless we assume that decision-makers have perfect foresight about technological change and new goods (new rights). If we do not know what technological interdependencies will occur tomorrow, or when existing interdependencies lead to divergences between private and social valuations, or we have imperfect information about existing interdependencies, rights formulated today (the status quo) may be inapplicable tomorrow and thus not represent anyone's preferences.

I have not explicitly considered the costs of reaching legal decisions and assigning rights. This is clearly an empirical issue, but some points can be made. Assigning the total court costs involved in litigation to the party losing the case will of course act as a deterrent to risk averse plaintiffs. The government could consider providing public legal aid to, for example, low income plaintiffs or offer social legal insurance to offset the cost deterrents. In evaluating the operation of the legal system, one should also consider the costs of enforcement, plus the costs of altering legal decisions. Legal institutions (as nonmarket allocation mechanisms) have the
drawback (relative to private markets) that they are inflexible with slow adjustment made to changes in events and technology.

B. Alternative Liability Rules

In this chapter, I have discussed some examples of legal rules for establishing rights and assigning liability in cases of stochastic and information externalities. I shall now consider the formation of contingent rights and their possible effects on incentives and individual behavior in more detail. The assignment of contingent rights and liability is more complex than the case of prior rights. In general, I will assume that the assignment of prior rights only applies to stochastic externalities. Contingent rights apply to information externalities. That is, rights and liability will be assigned by the legal system based on the level and nature of activities undertaken by the afflicted and generating parties prior to the occurrence of the uncertain event.¹ We have already mentioned some examples of tort laws specifying contingent rights: strict liability, the Hand rule, contributory and comparative negligence.

¹ Diamond (1974a) distinguishes between care and activity as separate variables, and between activities and events. An activity is what an individual was doing at the time of the particular event. Care pertains to the level and nature of the activity. For example, if the event is an accident, one individual's activity is crossing a street, care is whether he looked before crossing, wore bright clothing, etc. I see no need to distinguish between care and activities. We can simply define an activity jointly with care and assume that the courts monitor the individual's activity level and composition.
As we saw in Chapter III, private insurance markets may not operate in cases of information externalities due to nonconvexities and the difficulty of monitoring activities. The basic difference between insurance markets and liability systems is that the latter allocates resources ex post. Legal systems thus have the benefit of obtaining and utilizing more information that do insurance markets. Ideally both market and nonmarket systems would monitor activities prior to the occurrence of the event, but it is generally assumed that the costs of monitoring would be prohibitive. Insurance would also approximate the legal system if insurers required the insured parties to show proof that their activities did not contribute to the event. Unfortunately, private insurance would tend to be asymmetric; that is, insurance will only be sought by afflicted parties. Generators will never have any incentive to alter their activities. Legal systems have the ability to affect the activities of both generators and afflicted parties.

I shall now enumerate and explain possible sets of liability laws, then show how different laws can affect agents' behavior and resource allocation with information externalities. The possible laws will not in general achieve an optimal allocation of resources (in the traditional sense), but some social improvement is possible. Again, we may wish to redefine the concepts of optimality and social welfare in the context of legal rules rather than in the framework of competitive markets. In section C of this chapter, optimality will be defined relative to an
individual's level of care (preventive activities). Given that all individuals are below their optimal level of care, a social improvement occurs if a legal rule induces one party to increase his care level without decreasing the care levels of any other individuals. Note also that efficiency is always relative to the assignment of rights. Again, I am not explicitly considering the costs of formulating and implementing legal rules. One should note, however, that the legal system tends to have high fixed costs. I am only considering one aspect of the legal system, laws and legal rules. One would suspect that the average variable cost schedule for legal rules is relatively flat (or L-shaped).

It is assumed that legal systems cannot monitor the probability-dependent activities of agents prior to the occurrence of the event for two reasons. First, monitoring is likely to be costly in many cases and techniques for detecting certain activities may not exist. Secondly, it is often not known prior to the event what activities to monitor or which parties are involved. Even after the event occurs, it may be difficult to identify either the generating party in an information externality, or the activity he was engaged in which affected the probability of the event. I will ignore this problem and assume that the legal system can identify the activities of both agents involved in an information externality. The legal decision-makers must also be able to discern the veracity of the individuals as each type will have an incentive to reveal false information about
his involvement in the event. Thus, the legal system (like private markets) faces information problems even though its monitoring and rights assignment is *ex post*.

A distinguishing characteristic of liability laws is the due care standard. The due care standard is a threshold level of the preventive (or causative) activity established by the legal system for all recognized activities and is used as a rule for determining negligence. The legal system, in formulating contingent rights, examines the event *ex post* and attempts to determine whether any of the parties' *ex ante* activities contributed to the event. Those activities which the system determine to have affected the probability of the event are referred to as proximate causes. It is against these proximate cause activities that care standards are imposed. The legal system thus has two decisions to make even prior to liability assignment; what constitutes a proximate cause activity and at what level does this activity (or lack of it) become negligence. The criteria the legal system uses in their evaluations may be unrelated to any economic efficiency criteria. I will not consider the process of determining proximate causes or what constitutes negligence.

If a preventive (causative) activity is below (above) the care standard, the agent is judged negligent and, depending on the legal rule in effect, may be held liable for any losses suffered in the event. Due care standards thus act as quantity constraints on individuals' actions. With information externalities, separate care standards are needed for the activities of the afflicted and
generating parties. Diamond (1974b) calls this a two-activity incident as opposed to a single-activity event where both parties are engaged in the same activity. Liability in the two-activity case is much more complex because negligence is dependent on the care level of each party relative to the care level of the other party.  

Care standards thus can provide incentives for both parties to consume or produce more preventive activity (less causative activity). Agents may alter their behavior such that they no longer ignore the effect of their actions on the utility or output of others, i.e., liability rules may internalize externalities. Standards can, for example, induce afflicted parties to increase their preventive activities and generating parties to reduce their exacerbating activities from what they would be in an unregulated, uninsured situation (or even from an insured point as well). The change in activity level would thus decrease the probability of the event and in turn decrease the need for litigation to determine liability.

1 Liability does not necessarily imply that compensation must be made. If the afflicted party is held liable for an event because, his care level fell short of the standard, he would not have to compensate the generating party. He merely would not have the rights to receive compensation for his losses. See Diamond (1974a, 1974b) and Green (1974a) for their discussion of due care standards.

2 Recall from Chapter III that in an unregulated (and perhaps insured) situation, any increase in the generating activity was accompanied by a decrease in the afflicted party's activity (in the convex region of probabilities and preferences), thereby increasing the probability of the event.
One other characteristic of liability laws is that they generally assign the total costs incurred in the event (and subsequent litigation) to one party or the other. Costs are never shared. Whether or not cost-sharing makes sense depends upon the distribution of costs prior to liability assignment. The appropriate sharing rule could lead to an "optimal" level of externality internalization by making each party take into account both his own costs and those of others in decreasing the probability of the event.

There are thus two possible ways in which liability laws can generate efficient allocations. First, the optimal preventive care level can be sought with due care standards. Secondly, if care levels cannot change in response to standards (due for example to fixed coefficients in production or consumption; no abatement technology), the optimal compensation and liability assignment could be determined after the event.

The taxonomy of liability laws is derived as follows. A care standard is set for the proximate cause activities of afflicted and generating parties. A different standard must be established for each party. Let $S_A$ be A's care standard and $S_G$ be the standard for G. Each party has three options: He can either meet or exceed the care standard, or he can choose not to meet the standard. As I have assumed (in Chapter III) that afflicted parties' activities diminish the probability of the event, while generating parties' activities increase probability, the standards will be asymmetric. That is, A's
standard will impose a lower limit to the activity, while G's will impose an upper limit.

Given the individuals' decisions to meet or not meet the standard, possible liability laws then depend on the parties' relative positions. I will use the following schematic matrices to show the meaningful combinations of individual behavior and liability law. After enumerating alternative liability laws, I will then show their possible effects on individuals' care level decisions. That is, the care standards specify negligence and the legal rules determine liability. The question is then what effects the alternative legal rules have on afflicted and generating parties' interdependent choice of activity (care level), and the resulting equilibrium levels of the activity. We may then compare the equilibrium levels of both parties' activities with and without legal rules, and the resulting imposition of liability.

In the following table (Table II), a + will signify liability assigned to the generator (rights to the afflicted party), while a 0 represents no liability to the generator (generator's rights), that is, the afflicted party bears the liability. Individual A (the afflicted party), is defined as negligent whenever his activity is less than his standard (denoted \( S_A < S_A \)), and non-negligent when his activities exceed his standard (denoted \( S_A \geq S_A \)). G (the generating party), will be negligent when his activities exceed his standard (denoted \( S_G > S_G \)) and non-negligent when his activities are less than or equal to his standard (denoted \( S_G \leq S_G \)).
<table>
<thead>
<tr>
<th>Rule</th>
<th>A's Activities</th>
<th>G's Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( \geq S_A )</td>
<td>( \leq S_G )</td>
</tr>
<tr>
<td>(1)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>(2)</td>
<td>( \geq S_A )</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>( &lt; S_A )</td>
<td>+</td>
</tr>
<tr>
<td>(3)</td>
<td>( \geq S_A )</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>( &lt; S_A )</td>
<td>0</td>
</tr>
<tr>
<td>(4)</td>
<td>( \geq S_A )</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>( &lt; S_A )</td>
<td>0</td>
</tr>
<tr>
<td>(5)</td>
<td>( \geq S_A )</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>( &lt; S_A )</td>
<td>0</td>
</tr>
<tr>
<td>(6)</td>
<td>( \geq S_A )</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>( &lt; S_A )</td>
<td>0</td>
</tr>
<tr>
<td>(7)</td>
<td>( \geq S_A )</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>( &lt; S_A )</td>
<td>0</td>
</tr>
<tr>
<td>(8)</td>
<td>( \geq S_A )</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>( &lt; S_A )</td>
<td>0</td>
</tr>
</tbody>
</table>

Table II: Legal Liability Rules
I can explain the distinctions between the cases by assuming that the type of liability rule chosen by the legal system depends on the information (technological) the court has, or can obtain about afflicted and generating parties' level of care or activities prior to the occurrence of the event.\textsuperscript{1} Cases (1) and (2) impose strict liability on one party or the other. The courts may impose strict liability when it is impossible to determine and monitor the care levels taken by both parties prior to the event. Due care standards are thus inoperative under strict liability rules. This type of liability rule will have strong asymmetric incentive effects on both parties (see sections C.1 and C.2).

If the legal system cannot monitor A's activities, but can monitor G's, it may enact a rule that imposes liability on G whenever his care level is less than the standard, independent of A's activities. G is not liable when he meets or exceeds his standard. This is rule (3) (see section C.3). Due care standards thus exist only for G. Similarly, if A's activities can be monitored but G's cannot, the courts may enact a rule that imposes liability on G, independent of his level of care, as long as A's care level is greater than or

\textsuperscript{1} Again, one may wish to consider the relative costs of alternative rules, but I wish to concentrate on the effects of these rules on behavior, independent of costs. McKean (1970) discusses the relative transaction costs of some liability rules in the context of defective products, but uses intuitive arguments rather than a specific model or empirical evidence. McKean also fails to recognize the point that efficiency is relative to the legal rule that is in effect.
equal to the standard. This is rule (4) (see section C.4). G is not liable whenever A does not meet his standard. In rule (4) then only A has a due care standard. Rule (5) is known as negligence-contributory negligence, and is the most prevalent "real world" legal rule. It must be assumed under this rule that the court can monitor both individuals' care levels, thus placing, relative to the other legal rules, the greatest informational requirements on the legal system. Due care standards will thus be established for both parties. Under certain assumptions, this is the only rule which will lead to "efficient" equilibrium care levels (see section C.5). Rules (6), (7), and (8) are not too interesting nor are they very realistic alternatives for the courts, as the legal system must be able to monitor both parties' care levels. And, if it can determine these care levels, rule (5) would be imposed. If the courts cannot monitor care levels (or only certain parties' care), then rules (1-4) would be chosen. I will therefore not consider cases (6-8).

C. The Effects of Liability Rules on Nonmarket Equilibria

In this section, I consider the interaction between liability rules and individuals' choices of care levels. Essentially, the model is the information externality case examined in Chapter III, but simplified to some extent to focus on the effects of liability rules.

---

1 This is the case investigated by Diamond (1974a, 1974b).
I am following Diamond's model (1974b) with modifications to make it applicable to information externalities, rather than the accident cases he considers. I assume that a given legal rule has already been imposed by the legal system and is known by A and G. We would then like to know the effect of the due care standards on individuals' care levels. Individuals are uncertain about the occurrence of the externality, but not about how the externality affects them. They thus seek to maximize their expected utilities given the legal rule and due care standard by adjusting their level of care. I first consider possible equilibria under alternative rules, then discuss the "efficiency" of the resulting equilibria. Equilibrium consists of a set of decisions about the level of care taken by each party, given the care of the other party, and correct perception of the expected damages from the externality.

Let there be two individuals (or groups of identical individuals), A and G, who are assumed to be risk neutral only with respect to the bearing of accident costs. Both engage in activities which affect the probability of the event. The level of their activities is initially assumed to be alterable and it is assumed that the activities of both groups

---

The assumption of risk neutrality in accident costs simplifies the results. The introduction of risk averse behavior would not alter the basic analysis as long as it was assumed that all individuals within a given class had identical risk preferences. If attitudes toward risk vary, determination of equilibrium care levels becomes more difficult and it may be impossible to obtain definitive conclusions about care levels. Risk neutrality is a realistic assumption in this model as individuals have only one decision variable (their care level) and thus cannot diversify to spread their risks. Nor are contingent contracts available.
enter the utility functions of each. The activities are defined in
quantity space and confined to the unit interval. Both A and G are
assumed to have perfect information about the level of each other's
care. This assumption is rather unrealistic and I will briefly discuss
the possible consequences of asymmetric information about care levels
later in section D of this chapter.

\(U^A(x,y)\) is A's level of expected utility given his choice of
activity \(x\) and G's level of activity \(y\) (where \(x \neq y\)). That is, A and
G engage in different activities by assumption. Similarly, \(U^G(x,y)\)
describes G's expected utility of activity \(y\), given A's level of
activity \(x\). \(U^A\) and \(U^G\) are assumed to be strictly concave and twice
differentiable in \(x\) and \(y\) (I ignore possible nonconvexities). In
addition it is assumed that

\[
\begin{align*}
U^A_x(0,y) &> 0 \quad \text{for all } y, \\
U^G_y(x,0) &> 0 \quad \text{for all } x, \\
\lim_{x \to 1} U^A(x,y) &= -\infty \quad \text{for all } y, \\
\lim_{y \to 0} U^G(x,y) &= -\infty \quad \text{for all } x,
\end{align*}
\]

where \(U^A_x\) equals \(\partial U^A/\partial x\) and similarly for \(U^G_y\). These assumptions provide
upper and lower bounds for activities and are sufficient to ensure in­
ternal maximization and to deal with the discreteness of the care
standards.
Whenever the stochastic event occurs, A suffers damages. As we are considering *ex ante* decisions of individuals, these damages can be represented by an expected cost function, $C(x,y)$, which is assumed to be convex in $x$ and $y$, twice differentiable, and where $C_x > 0$, $C_y < 0$, $C_{xy} > 0$, $C_{xy} < 0$. Although I could cast this model into a state-preference framework, assuming the externality only occurs in state one, I will not do so as this would only complicate the analysis without adding any substantive results. We therefore only consider the behavior of A and G in the state in which the externality occurs.

1. **Strict Liability on A**

Given this background, we will now see how different liability rules affect the determination of care levels and standards. Rule (1), strict liability on A (G has the rights) is of course the situation that would occur if no legal system existed. It is therefore useful to consider this case as a benchmark against which to compare the legal rules. Presumably, the legal system could also arrive at a strict liability rule for individual A. A hypothetical rationale for this case is that A's activities have the major impact on the occurrence of the event (or only A has an abatement technology, G does not).

With strict liability on A, A and G maximize their expected utility independent of a care standard, but given each other's care level. An equilibrium would be characterized by the simultaneous solution to the
first order conditions of each individual. That is, we maximize $U^A(x,y) - C(x,y)$ with respect to $x$ and $U^G(x,y)$ with respect to $y$. A of course bears all the damage costs in this case. Maximization yields

$$U^A_x(x,y) - C_x(x,y) = 0$$  \hspace{1cm} (1)$$

$$U^G(x,y) = 0$$  \hspace{1cm} (2)$$

That is, each individual is maximizing his utility by choosing a level of care, given the care level of the other party (an exogenous variable each cannot control). It is assumed that $\partial U^A/\partial y < 0$ and $\partial U^G/\partial x \geq 0$; that is, G's activity decreases A's utility and A's activity either has no effect or increases G's utility. Also, we assume $U^A_{xy}, U^G_{yx} < 0$, i.e., increases in the activity by one party decrease the level of the activity taken by the other party.

Denote the care levels which solve equations (1) and (2) for all levels of $y$ and $x$ (respectively) by $\hat{x}_1 = \hat{x}_1(y)$ and $\hat{y}_1 = \hat{y}_1(x)$. Note that this equilibrium will not be optimal (in the traditional sense) because we have no assurance that $\hat{x}_1$ and $\hat{y}_1$ are set at levels which would result if the parties maximized their utility jointly. That is, if we maximize A's expected utility (including the damage costs), holding G's expected utility constant, the optimum levels of $x$ and $y$ would be the solution to the following expressions:
\[
\frac{\partial U^A}{\partial x}(x,y) - C_x(x,y) - \lambda \frac{\partial U^G}{\partial x}(x,y) = 0 \tag{3}
\]

\[
\frac{\partial U^A}{\partial y}(x,y) - C_y(x,y) - \lambda \frac{\partial U^G}{\partial y}(x,y) = 0, \tag{4}
\]

which, we recall from Chapter II, is the Pareto optimal equilibrium for public goods.

We now want to see how A's equilibrium level of care varies as a function of y and how G's equilibrium level of care varies as a function of x. This can be represented by supply functions or reaction functions (graphed in x,y space). The reaction functions are the solutions to equations (1) and (2), \( \dot{x}_1(y) \) and \( \dot{y}_1(x) \). We now want to know the slopes of these functions, so we differentiate (1) and (2) again. This yields

\[
\frac{dx}{dy} = -\frac{U^A_{xy} - C_{xy}}{U^A_{xx} - C_{xx}} < 0 \tag{5}
\]

\[
\frac{dy}{dx} = -\frac{U^G_{xy}}{U^G_{yy}} < 0. \tag{6}
\]

G then decreases his level of activity as A increases his care, and A decreases his level of activity as G increases his activity (decreases his care).
Given the negative slopes of (5) and (6), we can then plot the reaction functions as in Figure V.
We denote the equilibrium as \((x^0, y^0)\). It is important to note that nothing in the formulation of the model allows us to rule out the possibility of multiple solutions to equations (1) and (2), and thus, multiple equilibria. I therefore assume the existence of a unique equilibrium and also assume that it is stable. That is, each party adjusts sequentially to the other party's care decision. The necessary condition for local stability is

\[
\frac{dx}{dy} \left[ \hat{y}_1(x) \right] \frac{dy}{dx} \leq 1.1
\]

2. Strict Liability on G

I now assume that the legal system cannot monitor either A's or G's activities, but decides to impose strict liability on the generating party (gives afflicted parties the rights). Again, no care standards are imposed. One could argue that this is the other benchmark case, but differs from rule (1) in that legal costs may be incurred. That is, a legal system must exist before any kind of liability on generating parties can be imposed. If my analysis explicitly incorporated the legal system's costs, the equilibrium outcomes under rule (2) would clearly differ from those in rule (1). I shall show that even without introducing legal costs explicitly, rule (2) generates a different equilibrium than rule (1).

---

1 This follows from Diamond (1974b). This stability condition thus rules out cases where \( \hat{x}_1(y) \) is steeper than \( \hat{y}_1(x) \).
With no due care standards, G now bears all the costs suffered by A when the externality occurs. The utility functions of the two parties are now $U^A = U^A(x,y)$ and $U^G = U^G(x,y) - C(x,y)$. Simultaneous solution of the first order conditions of these expected utility functions will define an equilibrium. Again, we can describe the equilibrium with the reaction functions; solutions to the first order conditions. Let us denote these solutions as $\hat{x}_2 = \hat{x}_2(y)$ for individual A and $\hat{y}_2 = \hat{y}_2(x)$ for individual G. We assume the equilibrium is unique and locally stable. An equilibrium is then denoted by the point $(x^{oo}, y^{oo})$.

The imposition of liability will induce the liable party to increase his care level relative to that party's non-liable care level. From the initial assumptions, we know that each individual's care level decreases as the other party's care level increases. It then follows from the concavity of $U^A,G(x,y)$ and the convexity of $C(x,y)$ that the care level taken when one is liable exceeds the care level when one is non-liable.\(^1\)

Or, more generally, the greater the costs borne by the individual, the more care he takes. An intuitive explanation for this argument is that increases in care decrease the probability of the accident and thus decrease the expected costs the liable party must bear if the accident occurs. We have assumed that the generating party's activities are positively related to the probability of the externality. Therefore, when

---

\(^1\) See Diamond (1974b) for a more formal discussion of this point. The conclusion follows from the assumptions made about the signs of the second derivatives of each function.
G is liable, he will decrease the level of his activities. A's activities decrease the probability, so he too will decrease his activities under rule (2) as he is non-liable. That is, for any \( x \) or \( y \), \( \hat{x}_1(y) > \hat{x}_2(y) \) and \( \hat{y}_1(x) > \hat{y}_2(x) \).

Let us then consider the possible equilibrium situations when both parties decrease their activities. There are three possible outcomes (six, if one or both parties cannot change their activity level). The equilibria depend on the relative shifts of the reaction functions. If both parties respond identically, i.e., they shift their reaction functions by the same amount, then the equilibrium \((x^{oo},y^{oo})\) is characterized by \( x^o > x^{oo} \) and \( y^o > y^{oo} \) (see Figure VI). If A decreases his activity by more than G, then it is possible (but not always true) that \( x^o > x^{oo} \), but \( y^o < y^{oo} \) (Figure VII). And finally, if A decreases his activity by less than G, then it is possible that \( x^o < x^{oo} \), and \( y^o > y^{oo} \) (Figure VIII). It is also possible that, in some cases, \( x^o = x^{oo} \) or \( y^o = y^{oo} \). There is no way in which we can predict unambiguously where the final \((x^{oo},y^{oo})\) equilibrium will lie relative to \((x^o,y^o)\) unless we know the precise shifts of each party's reaction functions, or that one party cannot adjust his activity at all. This ambiguity is paradoxically very important, as it implies that determining the effect of a shift in liability from A's to G's depends on the technological information the legal system has about A's and G's reaction functions. If the legal system can determine the relative abilities of both parties to change the level of their activities, it may be able to enact a simple strict liability rule that improves
In rule (1) (strict liability on A), G parties have no incentive to reduce their activities as they bear none of the damages. Only As suffer. Conversely, in rule (2) (strict liability on G), As have little incentive to take care as they are compensated for damage. One suspects however that there will be asymmetries if A has to incur legal fees to show that the G are responsible for the externality. G incurs no legal fees as no payments are made. A's may thus have a higher level of care relative to Gs when they are both (alternatively) non-liable.

3. Liability on G, Independent of A

I now turn to consideration of a case in which the legal system has limited ability to monitor individual's activities; rule (3). I assume that the legal system is able to determine G's level of activity prior to the externality, but cannot monitor A's activities. The legal system thus establishes a due care standard for G, $S_G$. No standard can be established for A (and x activities). One possible legal rule is then to hold G negligent and hence liable for A's damages whenever he does not meet his due care standard, that is, whenever the level of his activities, $y$, exceed $S_G$, independent of A's level of activity. G's expected utility will then be

\[ U_G = \text{\textup{Expected Utility}} \]

\[ \text{\textup{Expected Utility}} = \begin{cases} \text{Payment} & \text{if } y > S_G \\ 0 & \text{if } y \leq S_G \end{cases} \]

See part D of this chapter for an elaboration of this argument.
Recalling from rules (1) and (2), we denote the level of care (for a given \( x \)) that maximizes G's utility when he is non-liable by \( \hat{y}_1 \), where \( \hat{y}_1 = \hat{y}_1(x) \) is the solution to \( U_y^G(x,y) = 0 \). Then, \( \hat{y}_2 \) is the level of care which maximizes G's utility when he is liable, i.e., \( \hat{y}_2 = \hat{y}_2(x) \) solves \( U_y^G(x,y) - C_y(x,y) = 0 \). When generating parties are liable, they thus decrease their activities. We can represent G's expected utility functions as follows (Figure IX). \( U_y^G(x,y) \) is the relevant curve when G is non-liable, while \( U_y^G(x,y) - C(x,y) \) is G's utility function when liable. Note that to interpret Figure IX, one must read from right to left, recalling that the standard is an upper bound on G's activities.

The imposition of a care standard makes only certain portions of these expected utility functions relevant. G will choose to be negligent or non-negligent depending on the level of \( S_G \). There are three possibilities. First, consider \( S_G > \hat{y}_1 \). G's utility function becomes the dotted line in Figure X, with its maximum at \( \hat{y}_1 \). G will choose to be
non-liable at all levels where \( y < S_G \) and maximize his utility at \( \hat{y}_1 \).

If \( \hat{y}_2 < S_G < \hat{y}_1 \), G's utility function becomes the dotted line in Figure XI. In this case, G will exactly meet the due care standard, \( S_G \), as he cannot maximize his utility on either utility function.

If \( S_G \) exceeds \( \hat{y}_2 \), we have to compare the standard which gives the same utility on \( U^G(x,y) \) as the maximum level of \( U^G(x,y) - C(x,y) \) to determine the individual's care choice. That is, it is the care standard that equates \( \hat{y}_2 \) (the maximum of \( U^G(x,y) - C(x,y) \)) with a point on \( U^G(x,y) \).

The rationale behind this point is that an individual will never choose
a point that gives him less utility than the maximum of his function when liable. Call this level of care $\bar{S}_G$. $\bar{S}_G$ is illustrated in Figure XII. If the due care standard is between $\hat{y}_2$ and $\bar{S}_G$, G will choose to exactly meet the standard. If $\bar{S}_G = \bar{S}_G$, the individual will choose to be negligent and maximize his utility at $\hat{y}_2$.

These results can be summarized as follows:

<table>
<thead>
<tr>
<th>Due Care Standard:</th>
<th>Choice for G</th>
</tr>
</thead>
<tbody>
<tr>
<td>$S_G &gt; \hat{y}_1$</td>
<td>$\hat{y}_2 &lt; S_G &lt; \hat{y}_1$</td>
</tr>
</tbody>
</table>

Optimal Level of Care: $\hat{y}_1$, $S_G$, $\hat{y}_2$

Table III: Optimal Care Levels for G

4. Liability on G, Dependent on A

I now assume that the legal system can obtain information about the level of A's activities prior to the occurrence of the externality and can thus define a due care standard for A, but no information can be
obtained about G's activities. We now consider legal rule (4). The legal system thus cannot determine when G is negligent, and defines liability to be dependent on A's activities. The legal rule specifies that G is liable whenever A meets or exceeds his due care standard, independent of G's care level. We must therefore examine A's choice of care as a function of his due care standard. The arguments are analogous to the previous case, but reversed because the standard imposes a lower limit on A's activities.

In this case, A will be held liable for the damages he incurs whenever his activities fall short of his due care standard, $S_A$. He is not liable whenever he meets or exceeds the standard. A's expected utility will therefore be

$$U^A = \begin{cases} U^A(x,y) & \text{if } x \geq S_A \\ U^A(x,y) - C(x,y) & \text{if } x < S_A \end{cases}$$

(8)

$x^2$ is the value which maximizes A's utility when he is not liable, and $x_1$ maximizes his utility when liable. We can again illustrate A's utility functions when liable and non-liable (Figure XIII), noting that we now read left to right.

Figure XIII
Note that $\hat{x}_1$ exceeds $\hat{x}_2$; the individual takes more care when liable.

Individual A will again choose three different levels of care, depending on the location of the care standard. Rather than illustrate the cases, I will summarize the results in Table IV.

<table>
<thead>
<tr>
<th>Choice for A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Due Care Standard:</td>
</tr>
<tr>
<td>Optimal Level of Care:</td>
</tr>
</tbody>
</table>

Table IV: Optimal Care Levels for A

G will then be liable independent of any care level he takes whenever A's due care standard is greater than $S_A$. One would not expect G to take any care in this case as the level of G's activities do not affect his liability. That is, G will choose to be negligent and be at $\hat{y}_2$. This conclusion differs from that of rule (3) because even though A had no standards imposed in (3), he may still take care to decrease the probability of being damaged by the externality. This occurs because G can choose to be non-negligent and A thus bears the liability (i.e., damages) if the externality occurs. In rule (4), G will take no care because no standard is imposed on him. Thus cases (3) and (4) are not symmetric.
5. Negligence - Contributory Negligence

We now turn to the case where the legal system can monitor the activities of both A and G. Due care standards are established for both parties and the legal rule specifies that G is liable only when he does not meet his care standard and A meets or exceeds his care standard. The analysis in this case becomes more complex as we must determine if and when an equilibrium exists for any pair of due care standards \((S_A, S_G)\). This is an important legal rule as it requires both parties to take care and allows for the possible attainment of "efficient" equilibria.

Following Diamond (1974b) and using the results of rules (1) through (4), we can define five possible equilibria that are attainable with the negligence- contributory negligence rule. Each individual has three choices: (1) to be negligent and maximize his utility, \(U(x,y) - C(x,y)\); (2) to be non-negligent and maximize his utility, \(U(x,y)\); or (3) to exactly meet his due care standard. The equilibria follow from the assumptions that the legal system imposes liability only on one party. Thus, only one party bears the damage costs in any equilibrium. This rules out cases where both meet their standards or both are non-negligent. An individual will exactly meet his due

---

Diamond did not seem to recognize that five equilibria are possible with rule (5). He did not consider that both parties could be negligent simultaneously. In this situation, A is liable. This result can be verified by referring back to the negligence-contributory negligence rule on page 105. Diamond (1974b) also considered the possibilities of multiple equilibria and non-existence. I will not deal with these problems.
care standard only when he can thereby avoid liability, i.e., when the other party bears the costs.

The following two tables define the possible equilibria and show the due care standards necessary to attain the equilibria.

<table>
<thead>
<tr>
<th>Choice for Afflicted Party</th>
<th>Choice for Generating Party</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chooses to be negligent</td>
<td>Chooses to be non-negligent</td>
</tr>
<tr>
<td>((S_1))</td>
<td>((Y_1))</td>
</tr>
<tr>
<td>At Due Care standard</td>
<td>At due care standard</td>
</tr>
<tr>
<td>((S_A))</td>
<td>((S_G))</td>
</tr>
<tr>
<td>Chooses to be non-negligent</td>
<td>Chooses to be negligent</td>
</tr>
<tr>
<td>((S_2))</td>
<td>((Y_2))</td>
</tr>
</tbody>
</table>

Table V: Equilibria under Negligence-Contributory Negligence Rule

Combinations of \((S_A,S_G)\), \((S_A,Y_1)\), and \((S_2,S_G)\) are ruled out by the assumption that only one party bears the damage costs. For example, if \(G\) is at his due care standard and thus not liable, \(A\) would never choose to remain at his due care standard or be non-negligent because he bears the costs in this situation. A similar argument applies if \(A\) is at his due care standard and \(G\) is liable.
Why should we be concerned about the type of equilibrium that occurs? In general, equilibria of types I and IV will not be "efficient". That is, they will not lead to an equilibrium that internalizes the damages that result from the externality. Equilibria of types II and III may be "efficient" (if they can be attained). Efficiency in the context of legal rules is however somewhat peculiar (relative to the traditional concept of efficient allocation with externalities).\(^1\)

Full efficiency would require both parties to base their care decisions on the total costs involved in the event, as we showed in part C.1 of

\(^1\) The nature of the efficient allocation was noticed by Diamond (1974b).
this chapter (equations (3) and (4)). That is, A incurs the damage costs if the externality occurs and both parties incur costs of taking care. Ideally, the legal system would allocate the total costs of the event, but in this model, it only deals with the recognized damages resulting from the externality. That is, it does not attempt to jointly maximize the two individuals' utility functions with the externality. A modified definition of efficiency is thus that each party makes his care decision dependent on his own costs and on the legally recognized costs. (Diamond, 1974b). This "efficient" position can be described by the equations

\[ U_x^A - C_x = 0 \]
\[ U_y^G - C_y = 0 \]

(9)

The legal system thus ignores \( U_x^A \) and \( U_y^G \), and, if these derivatives are non-negative in equilibrium (for all values of \( x \) and \( y \)), full efficiency cannot be attained. This does not mean however that no social improvement occurs. As we noted before (part A of this chapter), social improvement can be said to occur whenever one party's care level increases and no other individuals' care decreases (assuming no one is at their optimal care level). The modified efficient equilibrium can be attained with certain due care standards and legal rules.

Denote the solution to (9) as \( (x^*, y^*) \). Now let us see which types of equilibria will attain this solution. The efficient point will satisfy the equations
\[ x^* = \hat{x}_1(y^*) \]
\[ y^* = \hat{y}_2(x^*) \]  

That is, both parties act as if they were liable for the damages.

Figure XIV shows the resulting "efficient" equilibrium compared to the equilibria attained under legal rules (1) and (2). We assume a parallel shift of both reaction functions, although this is not a necessary assumption as the results are the same for any relative shift of the functions (assuming neither function is fixed).
Notice that the "efficient" equilibrium leads both parties to take more care than with either of the strict liability equilibria. That is, A increases his activities, G decreases his activities, as both act as if liable. \((x^*, y^*)\) thus shows the maximum attainable care levels possible under any legal rule and care standard combination. It is in this sense that it can be said to be "optimal".

Equilibrium of types I and IV will not lead to an \((x^*, y^*)\) solution as they do not induce both parties to act as if they were liable. Only equilibria of types II, III, and V can attain \((x^*, y^*)\). II and III imply that one party is liable, and the other threatened with liability if he drops below his due care standard. In V, both parties act as if liable. None of the other legal rules considered in this section will achieve type II, III, or V equilibria and thus cannot attain the "efficient" solution.¹

If the legal system has sufficient information to be able to establish due care standards and evaluate individuals' activities, and it wishes to attain "efficient" equilibria, legal rule (5) (negligence-contributory negligence) and care standards as specified by Table VI for equilibria of types II, III, or V could be implemented. Before advocating what the legal system should do, we need to know the costs of implementing and operating due care standards. These costs would also include the repercussions of setting the due care standard at a

¹ Other types of legal rules (for example, (6), (7), and (8)) may achieve type II, III, or V equilibria. I have not considered these rules as they tend to require as much information as negligence-contributory negligence and would thus not have any advantage over this rule.
level that prevents the attainment of a type II, III, or V equilibrium.

If the legal system has imperfect technological information, it cannot determine prior to the event, the effect of its standards on the care taken by individuals. The legal system will not know if its standards are too high (for A) or too low (for G) unless it knows the utility functions of both A and G when they are held liable and nonliable. What we have is a situation analogous to moral hazard in insurance markets; the choice of the due care standard plus legal rule affects individuals' behavior and hence the probability of the externality's occurrence. The legal system has an advantage over private insurance markets with respect to this moral hazard problem in that it has the ability to alter the care standards and legal rules (hence, contingent rights), if it finds that the standards and rules lead to inefficient equilibria.

D. Conclusion

We have seen that legal rules can lead to a type of efficient equilibrium where there exist information or stochastic externalities. There is the possibility under certain legal rules that equilibria will be non-existent or inefficient due to the discreteness of the due care standards. But there exist other combinations of legal rules and care standards that will achieve our modified efficiency criterion. The legal rules which lead to efficient outcomes are however more complex
(negligence-contributory negligence) than the rules which will not in general generate efficient equilibria (strict liability rules) in that they require more information and more precise specification of due care standards. If the legal system cannot set standards at the levels which will lead to efficient equilibria, the simpler rules may be preferable. That is, there is no guarantee, if the legal system is uncertain about the imposition of due care standards, that the resulting equilibria will be different from the solutions attainable under the simpler rules.

Although the outcome of legal rules may be uncertain (i.e., the legal system may not know if specific sets of rules and standards will yield efficient equilibria), the legal system may have an advantage over private insurance markets (if they exist). Legal rules may lead to increases in social welfare because they can provide the appropriate incentives to parties. Whether the equilibrium is efficient or not, rules and standards will induce parties to increase their care levels to avoid liability. Increased care decreases the probability of the externality's occurrence. Without a complete analysis of all the transaction costs involved in an information externality, we cannot say definitively that an outcome is (or is not) optimal.

The assumptions of the model presented in this chapter are fairly restrictive. In particular, it is assumed that all individuals of type A or G are identical in all respects. It is also necessary to have A and G groups be the same size, or the transfer of liability through the legal system from one group to the other will be asymmetric. That is,
we would have to alter the cost functions depending on which party was liable. The model is also peculiar in that it requires compensa-
tion to be one-on-one. We are assuming that no public goods' problems arise (free riders, non-revelation of preferences). With legal rule (4) for example, each member of the G group compensates an A party, or the total G compensates total A. We do not worry about the distri-
bution of compensation (or bearing of liability) within each group. This assumption may not be too unrealistic in some cases, e.g., class action suits in the United States where the liable parties make a total settlement, distributed equally amongst the parties awarded the contingent rights. The model is appropriate in this situation because the afflicted parties are identical.

Will legal rules generate "efficient" equilibria (or any equilibria) when individuals are not identical? I will not analyze this question formally, but point out some of the difficulties encountered with legal rules and nonuniform individuals. Individuals within each group can vary with respect to the effects of their activities on the probability of the event, the productivity cost of the activities, their income level and distribution, and their spatial location or distance from the other group. For example, if the agents involved are firms which are identical in all respects except for their distance from each other and from members of the other group, these agents are no longer identical. Ideally, the legal system should be able to distinguish between individuals

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1 Diamond (1974a, 1974b) and Green (1974a) consider formally the problem of nonuniform equilibria in the context of accidents.
and implement nonuniform (differential) due care standards. The legal rules would be unaffected. Implementing differential care standards requires more information and thus increases the costs of operating the legal system. There is also the problem of legal justice. The legal system tends to operate on the principle that all individuals should be treated equally, and this was the case in the model presented in this chapter. If differences between individuals are small, then equal treatment, that is, one standard for each group and no sharing of costs, then due care standards set at their optimal point for the legal rules can achieve "efficient" equilibria. In general, as the disparity amongst individuals widens, uniform care standards on the nonuniform individuals will no longer lead to "efficient" equilibria. The legal system must then impose different standards on the nonuniform individuals if it seeks efficient outcomes. It must also weigh the costs of obtaining the additional information necessary to define these standards against the efficiency gains. Again, there may be a preference for simpler legal rules and care standards given the uncertainty of the outcome.

The model also stipulates that individuals in each group know precisely the level of care taken by individuals in the other group. If this assumption is dropped, we may again favour the simpler rules (1) through (4) which do not presume that the liable party has any information about the non-liable party's activities.

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1 Green (1974a) proves this assertion for the case where individuals vary in the costs of taking care.

2 One could also revise the model by assuming that the activity level is
If the legal system cannot obtain enough information to establish the due care standards necessary to achieve efficient equilibria, can we say anything about the rule it should impose? Under certain assumptions, I think we can. We found in section C.5 that the "efficient" levels of care \((x^*, y^*)\) lead to the lowest \(y\) and the highest \(x\) of any legal rule. This result was only attainable (potentially) under negligence-contributory negligence. The question is, can we approximate \((x^*, y^*)\) with a simpler liability rule? What would be the result for example of moving from a strict liability rule on A to strict liability on G?

The technological information the legal system has about A's and G's reaction functions is crucial to the answer to these questions. We know from our analysis of strict liability of G (rule 2), that the response each individual makes to the imposition of liability depends on his ability to change the level of his activities. Different responses lead to different equilibrium solutions. If the legal system has information about each party's response to liability (how its reaction functions shift relative to each other), it may be able to impose a strict liability rule that results in a social improvement. That is, we may move unambiguously closer to \((x^*, y^*)\).

If, for example, we have a situation as depicted by Figure VIII (page 117), then G's shift their activities down in response to an imposition of liability relatively more than A's decrease their activity in response to non-liability. Strict liability on G will thus lead to an stochastic. Diamond (1974a) considers this problem for single-activity accident cases, and the results are quite messy.
(x^0, y^0) where x^0 > x^* and y^0 < y^*, i.e., we move towards x^*, y^*; and both parties are induced to take more care. Figure XV illustrates this case.

Figure XV may be representative of many real world externality cases. Take our botulism example from Chapter III. If food processing firms can identify the cans that contain botulism toxin at little expense (e.g., employing someone to monitor the cooking temperature), while consumers cannot tell which cans contain botulism except at great expense (e.g., running chemical analyses or feeding suspicious cans to their pets), imposing strict liability on processing firms will lead to a solution as depicted by (x^0, y^0) in Figure XV.

The same result occurs if we know that A's cannot adjust their activity at all, but G's can. Or alternatively, if only A's can modify their activities, strict liability on them will lead to an (x^0, y^0) that approaches (x^*, y^*) without a decrease in the level of care taken by one
party. Only if A and G have parallel shifts in their reaction functions, do we get the result that strict liability (on either party) increases the care level of one individual, while decreasing the care level of the other (or, in the context of activities, it increases A's activity and decreases G's activity, or decreases both A's and G's activities). The parallel shift case would seem to be a special case. We might expect that A's and G's reactions functions are asymmetric in many externality cases.

The legal system, in these cases, does not need perfect technological information (unless it wants to compute equilibria precisely). All it needs to know is the relative ability of afflicted and generating parties to engage in activities that reduce the probability of the externality's occurrence.

This is a very encouraging result in an analysis that has been overwhelmed with market failures and potential non-existence of equilibria. The legal system may thus not be superior to market systems if we evaluate both in terms of technical economic efficiency, but we have found that relatively simple legal rules may lead to social improvements even though the externality is not fully internalized.
Let me conclude by briefly summarizing the results of this thesis. Chapter II first defined a legal rights taxonomy, then showed that resource allocation is affected by the assignment of rights in a decentralized economy given the existence of general externalities (both public and private), even when we assume zero transaction costs. The "Coase theorem" was shown to be invalid, except under restrictive assumptions about individuals' preferences.

Chapter III designed an information/externality taxonomy, then examined two cases, stochastic externalities and information externalities, to see if private insurance markets would arise to internalize these externalities. It was found that stochastic externalities present no problem for the creation of private insurance markets if prior rights exist and if actuarial values of the risks of the externalities' occurrence can be calculated by insurers. Information externalities on the other hand, introduced the possibility that competitive insurance markets and equilibria would not exist. Non-existence may occur because risks are not statistically independent and because individuals' expected utility functions may no longer be quasi-concave with information externalities. Insurance equilibria may exist, but are not necessarily efficient or optimal. It was generally found that the amount of information necessary to operate private insurance markets is substantial, and that perfect competition in insurance markets is incompatible with efficient equilibria when information is imperfect. Government insurance
or regulation of private markets may lead to some social improvement, but will not necessarily achieve first best optima.

Chapter IV considered the effect of legal liability rules and due care standards on the attainment of "efficient" equilibria, given an information externality. It was found that only the negligence-contributory negligence rule could achieve equilibria where all parties to an externality took the maximum care to prevent the externality's occurrence. The negligence-contributory negligence rule does require substantial amounts of information in the setting of care standards. If the legal system cannot obtain enough precise information to impose a negligence-contributory negligence rule, but can obtain information about the relative abilities of the parties to take care in preventing the externality, then it was shown that imposition of a strict liability rule on one party may lead to social improvement. First best optima are generally not attainable with legal rules.

Given the information necessary to operate private insurance markets and the inability of insurance to affect the behavior of all parties engaged in an externality, one becomes very pessimistic about the ability of private insurance markets to internalize private externalities that arise from imperfect information. Legal rules also fail to internalize externalities, but may lead to some social improvement using less precise technological information than is necessary for the operation of private insurance markets. The formulation of optimal policies for internalization of certain types of externalities is thus quite complex when one incorporates specific assumptions about the transaction costs that give rise to market failure.
VI. BIBLIOGRAPHY


