A Tale of Two Models (or is it Methods): Formal Theory in Economic Analysis of Law

by
Lewis A. Kornhauser[1]

1. Introduction

Economic analysts of law, when they do theory, often write down formal mathematical models. These models simplify greatly the phenomena they seek to illuminate. They thus raise similar questions to those raised by economic models generally (and to formal models in other social and natural sciences): What do the models teach us about the phenomena under study? How do the models teach us?

In this essay, I approach these questions through a case study of one of the most successful model in economic analysis of law, John Brown's model of accident law,[2] and a similar model developed nearly simultaneously by Peter Diamond in a series of three papers.[3] Brown's paper was very influential. Diamond's papers more or less disappeared from the legal

[1]Frank Henry Sommer Professor of Law New York University. The financial support of the Filomen d'Agostino and Max E. Greenberg Research Fund of the NYU School of Law is gratefully acknowledged. Gretchen Feltes provided research assistance.

[2]Brown, "Towards and Economic Theory of Accident Law," 2 *Journal of Legal Studies* 323 (1973). Becker's model of crime, "Crime and Punishment: An Economic Approach," 76 *Journal of Political Economy* 169-217 (1968) has many more citations than Brown's model but its influence has extended well beyond legal academia and economics.

[3]Diamond, "Single Activity Accidents," 3 *Journal of Legal Studies* 107-164 (1974), Diamond, "Accident Law and Resource Allocation," 5 *The Bell Journal of Economics and Management Science* 366-405 (1974), and Diamond and Mirrlees, "On the Assignment of Liability: The Uniform Case," 6 *The Bell Journal of Economics* 487 -5-6 (1975).

literature.[4] This disparate reception raises questions both in the sociology of knowledge and the philosophy of social science. Why did Brown's model succeed while Diamond's failed? What did we learn from Brown's model that had such resonance within economic analysis of law? What lessons did Diamond's model teach? Or perhaps did Diamond offer lessons that economic analysts of law failed to learn?

To understand the insights provided by the two models requires some knowledge of the state of debate over accident law in the late sixties and early seventies when the two models appeared. To frame this debate, I will again refer to two famous, and influential, works, each of which reflected an aspect of the debate: Richard Posner's "A Theory of Negligence"[5] and Guido Calabresi's book, *The Costs of Accidents*.[6]

These two works pursue two different projects within economic analysis of law. Posner's article is an early contribution to what I call "doctrinal analysis." Doctrinal analysis participates in the then (and still) dominant tradition of legal scholarship that seeks to rationalize legal doctrine.[7] Economic analysts of law thus offer an interpretation of the decided tort cases that

---

[4]The fate of the two papers contrasts starkly with the fate of the two authors. Brown disappeared from academia while Diamond went on to win the Nobel Prize in Economics (as did his co-author of the third paper).

[5]1 *Journal of Legal Studies* 29-96 (1972)

[6]Yale University Press 1970.

[7]"Doctrine" in the English, not the French, sense; "Doctrine" here translates as "la jurisprudence."

interprets them as announcing or implementing legal rules that are efficient.[8] Policy analysis, by contrast, deploys economics as a theory of behavior in service of whatever goals the policymaker might have. Legal rules reflect the aims of the policy maker but to promote these ends in an instrumentally effective way, the policymaker most predict the behavior that different legal rules will induce. The project of policy analysis in economic analysis of law may guide the policymaker in making these behavioral predictions.[9]

Table 1 lists the citation counts for each of the six works. Calabresi's book has been by far the most cited of the six but Brown's article has virtually the same number of citations as Posner's article and it received more than 3.5 times as many citations as the most cited of Diamond's articles, "Single-Activity Accidents" despite their focus on very similar issues. Brown's article received more than ten times the number of citations of "Accident Law and Resource Allocation" even though, as I point out in section 5 Brown's model is a special case of the model in Diamond's article.

Not surprisingly, Calabresi and Posner are predominantly cited in law publications though

[8]Posner to some extent initiated this program but he often used "efficient" in the sense of "Wealth maximizing" or "social welfare maximizing" or, as in the case of accident law, "social cost minimizing." I follow Posner's unfortunate practice here.

[9]At one point, scholars distinguished between the "Chicago School" and the "Yale School" of economic analysis of law. The Chicago School, typified by Posner, pursued what I have described as doctrinal analysis. The Yale School, however, was not understood as pursuing policy analysis. Rather, it sought more room for government intervention to achieve efficient outcomes. On the distinction between the schools, see Parisi, "Positive, Normative and Functional Schools in Law and Economics," 18 *European Journal of Law and Economics* 259-272 (2004).

this remains largely true for the four technical articles as well.[10]

Table 1
Citations of Referenced Works

Work	Date Published	Web of Science Citations	Law Cites#	Economics Cites#
Calabresi, The costs of Accidents*	1970	664	569	53
Posner, A Theory of Negligence	1972	361	308	34
Brown, Toward an Economic Theory of Accident Law**	1973	357	208	127
Diamond, Single Activity Accidents	1974	97	62	52
Diamond, Accident Law and Resource Allocation	1974	34	20	14
Diamond and Mirrlees, On the Assignment of Liability	1975	17	7	11

[10]Which include the Journal of Law and Economics, The Journal of Legal Studies, the Journal of Law Economics and Organization, the International review of Law and Economics, and The American Law and Economics Review. Indeed these five journals are the predominant source of citations for each of the technical articles. A crude, simple count identified 43 citations of Brown's article in "pure" law reviews, 15 of "Single Activity Accidents" in pure law reviews, 3 citation o f "Accident Law and Resource Allocation" in pure law reviews, and 2 of Diamond and Mirrlees in pure law reviews.

*Calabresi's book integrates several of his prior articles so the citation count for the book understates its influence
**Shavell's book *Economic Analysis of Accident Law* adopts and extends Brown's model and is often cited as the *locus classicus* for the model. So the citation count for Brown's model understates its influence.
#"law and economics" journals such as the Journal of Legal Studies, the Journal of Law Economics and Organization, etc are classified as both law journals and economic journals so the sum of the numbers in the last two columns may exceed the total number of citations to the article. Nor are the categories "Law" and "Economics" exhaustive so the sum may be less than the total.

The discussion proceeds as follows. The next section offers some general comments about models in general and modeling law in particular. Section 3 situates Posner's article and Calabresi's book within the debates of the times. Sections 4 and 5 summarize Brown's model and Diamond's model respectively. Section 6

2. Modeling Law

2.1 Models Generally

A model consists of a mathematical formalism and an interpretation that connects the formalism to the phenomenon under study. The model presents an extremely simplified account of the phenomenon under investigation.[11] The model may serve multiple purposes.

First, it might facilitate analysis of a problem. Formalization requires that the analyst make precise the often vague and ambiguous concepts used in verbal analysis. This precision may clarify concepts and help to understand the role that particular concepts or features play in

[11]The relation of model to world is very controversial within the philosophy of science. Some philosophers contend that the model "represents" the phenomenon. Others that the model is an analogue to the phenomenon or a "credible world" Or that the model "mediates" between the theorists and the world. Or that we should understand the model as a "narrative," a "fable," a "parable" or as an analogy to a "case" rather than a rule.

an argument or in a causal chain.[12] In addition, the formal language of mathematics facilitates reasoning about the interrelations among variables.

Second, a model might explain at least in part a phenomenon. In economics, a model may identify some causal mechanism at play. Typically, a model isolates a single causal mechanism within a complex social interaction. It thus offers a partial explanation of the phenomenon under investigation as there generally are multiple causal influences at work, some of which may inhibit, interfere with, or oppose the mechanism modeled and others of which might amplify or facilitate the mechanism studied..

Third, a model might allow one to make predictions. If one had a complete explanation of a phenomenon, then the explanation would generate accurate predictions. But partial explanation may not fare well as predictors as other, unidentified causes may supplement or interfere with the identified mechanism. One thus might predict better using correlates rather than causes.

Fourth, a model might assist in the making of policy or the design of an institution. As noted in the introduction, a policymaker must understand how different legal means would promote her ends. A model may at a minimum suggest potential unintended or unwanted consequences of a given policy. At best, it may indicate how individuals will respond to different legal rules.

---

[12]Of course, precision has costs as well. The analyst might choose to disambiguate in the wrong direction. Or the sense that is amenable to specification may not be the sense relevant to understanding the phenomenon under study. Or the precision may promote analysts to focus on the well-specified concerns ratehr than more important, but more elusive, concepts. (I.e. the model may encourage provoke analysts "to search for the lost keys under the street lamp rather than the shadows where they lie." But not all models are good models.

Finally, a model might serve as a benchmark. A benchmark may have a normative or a positive role. In a positive role, one might understand a benchmark as an aid to inquiry. Consider, for example, the "Coase Theorem" that states that, in a world of zero transaction costs, the assignment of a liability rule will have no behavioral effects. Observing a behavioral difference directs the analyst to search for the "positive" transaction cost that has produced the deviation from the benchmark phenomenon.[13]

2.2 Modeling Law

We might ask at least three big questions about legal rules . What is the content of a legal rule? What effects does the legal rule have on behavior? What explains (in a causal sense) the content of the legal rule? Each of these questions has provoked a research project in economic analysis of law. Call the project addressing the content of the legal rule "doctrinal analysis;" the project on the effects of legal rule "policy analysis;" and the project on the causes of legal rule "political economy."

Doctrinal analysis has been the central project of economic analysis of law at least since the publication of Posner's *Economic Analysis of Law.* Indeed, non-economic forms of doctrinal analysis have been the pre-occupation of lawyers and legal academics for centuries. Doctrine is a perspicuous presentation of judicial decisions. A typical doctrinal analysis extracts a set of rules

[13]The Modigliani-Miller Theorem in corporate fiannce provides perhaps a clearer example. The theorem identifies conditions – no bankruptcy, no taxes, no agency costs, and no asymmetric information – under which the capital structure of the firm has no effect on the production decisions of the firm. To understand why the capital structure of firms may vary requires investigation of each of these assumptions.

Notice that the Modigliani-Miller is simply a variant of the Coase theorem as the capital structure of the firm simply identifies who has which claims on the flow of income generated by the firm.

and principles that purportedly underlie a set of cases that resolve disputes within some domain. Phrased differently, an analysis of doctrine rationalizes the case law in the sense that it reduces the case law to a set of concepts and principles that generate rules that would largely "explain" the resolution of past cases.[14]

The project of doctrinal analysis in economic analysis of law argues that case law, at least in common law domains, are best rationalized economically. Each legal rule promotes social cost minimization. More specifically, Posner claimed, and doctrinal analysts seek to argue, that common law rules are efficient.

Policy analysis, by contrast, deploys economic methods to understand the effects that legal rules and institutions have on behavior. An understanding of these effects is central to the policymaking task. Policymakers use legal rules and institutions to pursue their policy goals; to do so they must understand how each proposed policy will influence policy.

Doctrinal and policy analysis are logically distinct enterprises. Legal rules might be efficient (in the sense that they induce efficient behavior) even if individuals do not respond to legal rules as economic analysts of law claim they do. Conversely, even if micro-economic theory provides a powerful theory of how individuals respond to legal rules, legal rules need not induce efficient behavior.

3. The State of the Legal Debate in 1971.

A great deal of intellectual ferment concerning torts and accidents roiled the courts,

[14]One might distinguish a "weak" and a "strong" form of doctrinal analysis. The text sketches the weak form that merely rationalizes the case law. The "strong" from both rationalizes and justifies the case law. It offers, that is, an interpretation of the case law that presents, if not in its "best light," at least in a normatively attractive light.

legislatures, and academia. *Hennigsen v. Bloomfield Motors*[15] completed the transformation of product liability from a contract doctrine to a tort doctrine. Legislatures, both in the US and abroad, were considering radical changes to the system of tort liability such as no-fault insurance. Brown's model and Diamond's models respond to this ferment.

Posner's "A Theory of Negligence" and Calabresi's *The Costs of Accidents* together provide a map of the terrain of tort in the early seventies. Posner identifies three elements to the "orthodox" view of torts at the time he wrote. First, the introduction of negligence in the mid-nineteenth century subsidized infant industries by externalizing the costs of "careless" production. Second, tort law primarily served to compensate victims for the costs of accidents she incurred.. Third, negligence is a moral concept.

Posner rejected all of these claims in favor of an "economic" reading of negligence doctrine. He argued that "the dominant function of the fault system is to generate rules of liability that if followed will bring about, at least approximately, the efficient – the cost-justified – level of accidents and safety." A major aim of the essay is thus to use "efficiency" as social cost minimization as the lynchpin of a rationalization of tort doctrine.[16]

Calabresi's *The Costs of Accidents* exemplifies the other strain of the debate over tort law. Calabresi thus does not search for efficient legal rules within the negligence regime; a regime that he thinks too costly administratively to be social cost minimizing. Rather he wants to compare different institutional regimes – enterprise liability, first and third -party no-fault

[15]Citation

[16]This aim is more evident in the first edition of Posner's nearly contemporaneous book *Economic Analysis of Law* Harvard University Press 1973.

insurance, social insurance coupled with risk management through regulation – that allocate risk. He engages explicitly in policy, rather than legal analysis.

Calabresi understands the purposes of tort law as the fair allocation of responsibility for accidents and the reduction of costs, understood as the (1) the number and severity of accidents, (2) compensation of victims, and (3) the costs of administering the system of risk regulation and compensation. He argues that policymakers might seek to balance these four concerns differently when faced with different types of risk. Society may not deploy the same regulatory scheme to control industrial accidents as the scheme designed for auto accidents or for the control of injuries that result from consumer products.

One may thus understand the book as undertaking the first half of a comprehensive policy analysis. Calabresi seeks to identify the social objective function in various realms of risk. But he does not engage in the complex, empirical exercise of evaluating how well various institutional arrangements satisfy each objective.

Posner and Calabresi thus launch two of the three projects in economic analysis of law.[17] Posner articulates and pursues doctrinal analysis; Calabresi articulates and pursues policy analysis. Diamond complements Calabresi's analysis by articulating formal models that promote each of these projects. Brown's model, however, has a more ambiguous relation to Posner's (and Calabresi's) project. Its success, in part, stems from a perceived connection to the doctrinal

[17]The third project which I call political economy seeks to explain why we have the legal rules and institutions that we in fact have. For a discussion of these three projects see Kornhauser, "Economic Analysis of Law," *Stanford Encyclopedia of Philosophy* (Fall 2017 edition), Edward N. Zalta (ed.) URL = <https://plato.stanford.edu/archives/fall2017/entries/legal-econanalysis/>

project though, I shall argue, this perception is mistaken.

4. Brown's Model

Brown derives his model from the theory of the firm. He defines the technology of accident prevention p(x,y) as dependent on two inputs, a care level x and a care level y. Care x has a price w_x and care level y has a price w_y. A firm would then choose (x,y) to minimize the total costs of production

$$C(x,y) = w_x x + w_y y + p(x,y)A \qquad (1)$$

where A is the loss imposed by an accident and p(x,y) is assumed strictly convex and interpreted as the probability an accident will occur, given levels of care x and y. Let (x*,y*) minimize C(x,y).[18]

Brown then argues that liability rules permit the decentralization of care decisions to two agents Xavier and Yvonne each of whom chooses one level of care, x and y respectively. He first defines a liability rule L(x,y;X,Y) as a simple function that identifies the share of the loss to be borne by Yvonne. Xavier bears the share 1 - L(x,y;X,Y). As before x and y represent the levels of care. I use X and Y to represent the standards of care used by the court.[19] More specifically, Brown focuses on "all-or-nothing" rules L(x,y; X, Y) that either allocate all of the loss to Xavier or all of the loss to Yvonne. Classical, nineteenth century rules of tort had this property, well-

[18]Brown writes the optimum as (X_Ω, Y_Ω).

[19]I have altered Brown's notation to make clear the dependence of the liability rule on the standards of care by including them as arguments of the function L. He writes the legal rule as L(x,y) thereby suppressing the dependence of the rule on the standards of care and de-emphasizing the potential for comparative statics. Also, Brown designates levels of care with capital letters and standards of care with asterisks.

captured in and illuminated by Brown's formalism.

Brown then shows that these all-or-nothing rules will induce his two agents, named Xavier and Yvonne, to choose the optimal levels of care (x*, y*) when the relevant standards are set either to X= x* and Y = y* or X= x* and Y = 0, or X = 0 and Y = y*. [20] These results follow from consideration of the individual decision problems of Xavier and Yvonne:

$$\min_x C_X(x,y) = w_x x + p(x,y)AL(x,y;X,Y) \qquad (1X)$$

and

$$\min_y C_Y(x,y) = w_y y + p(x,y)A[1 - L(x,y;X,Y)] \qquad (1Y)$$

5. Diamond's Model

The richness and complexity of Calabresi's *The Costs of Accidents* provoked Diamond to attempt to "set Calabresi to mathematics." He wrote, in quick succession, a series of three articles that share some formal structure.[21] The first two articles, as Diamond admits, address issues at

---

[20]Brown also formulates a proportional sharing rule that he calls "relative negligence" and later a pro rata sharing rule that Brown calls comparative negligence.. These rules are meant to capture a court that has limited information about the technology of care. These rules fail to induce the optimal standard of care. Cooter, Kornhauser and Lane (1979) however show that the relative negligence rules will, with the appropriate adjustment to the standards of care, converge to the socially optimal standards and hence, in the limit, induce the socially optimal levels of care.

Brown considers another class of rules that he calls strict liability rules – strict liability with contributory negligence (that parallels negligence) and strict liability with dual contributory negligence (that parallels negligence with contributory negligence). But this class of rules is identical to the class of negligence rules; it simply shifts the default bearer of liability, in essence renaming Xavier the "victim" and Yvonne the "injurer." As the loss is pecuniary, the liability rule simply identifies the agent to whom the loss "belongs" (or is assigned as a default).

[21]In the Introduction to "Single Activity Accidents," Diamond writes: "I started this project as an attempt to set Calabresi to mathematics, although the logic of my approach has drawn me away from that definition of the task."

best tangential to Calabresi's project but the final article models some central concerns of *The Costs of Accidents*. I treat all three articles as variants on a single model.

The first two articles stand in a complex relation to Brown's model. "Single Activity Accidents" present a model remarkably similar too but subtly different from Brown's model which Diamond characterizes as a model of two-activity accidents.[22] Naively, in single activity accidents, all agents engage in the same activity; auto accidents between cars of the same size are an example. In two activity accidents, by contrast, the agents engage in different activities; car-pedestrian accidents provide an example.

From an economic perspective, single activity accidents differ from two activity accidents (as modeled) in one important way. In single activity accidents and in a world with no cost shifting rules, an accident imposes costs on each party while in two activity accidents, an accident imposes a cost on only one party. As in Brown, the liability rule determines the conditions under which the external cost "borne" by each agent are shifted to the other party.

In this framework and with a legal regime of negligence with contributory negligence, Diamond shows how individual behavior changes as the standard of care changes. Incidentally, he shows that social costs are optimally minimized when the standard of care is set at the social

[22]Diamond's model is more complex. He considers a world with n+1 agents, not two. Moreover, he replaces the probability of an accident p(x,y) with an expected number of accidents $\pi(x,y)$ between any two agents. The expected number of accidents for each agent is thus $n\pi(x,y)$ He also permits the severity of the loss C(x,y) to vary with the care choices of the agents. He also replaces the cost of taking care with a function V(x) that may reflect other benefits or costs from adopting care level x.

cost minimizing level of care x*.[23]

"Accident Law and Resource Allocation" offers a model of two activity accidents of which Brown's model is a special case. Diamond formulates the problem as one of general equilibrium Let -A(x,y) be the utility of agents in activity 1 gross of any external costs that the activities jointly impose when Agent 1 adopts a level of care x and agent 2 adopts a level of care y. Let -B(x,y) be the utility of agent 2 in activity 2 gross of any external costs that the activities jointly impose. Let C(x,y) be the external costs imposed by the agents jointly engaging in activities 1 and 2 and that fall on either or both of the agents.[24] C(x,y) represents the external costs that can be shifted through the legal system. The social objective function is to minimize

$$W(x,y) = A(x,y) + B(x,y) + C(x,y). \qquad (2)$$

As before let (x*,y*) minimize W(x,y).

It is easy to see that Brown's model is a special case of this model; simply set n = 1, $A(x,y) = w_x x$, $B(x,y) = w_y y$, $\pi(x,y) = p(x,y)$ and $C(x,y) = A$. Clearly, a legal regime and standards of care can be chosen to induce the agents to minimize W(x,y). But it is equally clear that efficiency can be achieved in this way only if A(x,y) = A(x) and B(x,y) = B(x). Under these conditions, all the external costs can be shifted through the legal system. When some external costs can't be shifted, the liability system (by setting the standards of care equal to the efficient

[23]Diamond only considers uniform equilibria in which all agents choose the same care level.

[24]I have modified the notation to make more evident the common structure of Diamond (1974) and Diamond and Mirrlees and to Brown.

levels of care) will generally fail to achieve the social optimum.[25]

More importantly, Diamond is not interested in the question of efficiency or indeed social cost minimization. He seeks to understand how care choices vary with the choice of the standard of care. This goal derives from Diamond's interest in the policy analysis that Calabresi's project requires to choose the least cost avoider.[26] The final article "On the Assignment of Liability: the Uniform case," addresses this issue.

The framework here parallels that of the prior work; an additional function D(x,y), the external costs that fall on third parties or the government is included. The social cost function here is thus defined as

$$W(x,y) = A(x,y) + B(x,y) + C(x,y) + D(x,y) \qquad (3)$$

In this article, however, the policymaker is constrained to assign C(x,y) unconditionally to one party or the other. The policymaker is thus constrained to rules of strict liability (or no liability).

---

[25]The conclusion follows from examination of the objective functions of each agent. Agent 1 (Xavier) seeks to minimize $A(x,y) + \pi(x,y)C(x,y)L(x,y:X,Y)$. Obviously, he makes a socially non-optimal decision when $B(x,y) \neq B(y)$, i.e, when the choice of x affects the costs B(x,y) that fall on agent 2 (Yvonne)..

One might understand A(x,y) and B(x,y) as reflecting personal injury which of course is not transferable through the legal system (or otherwise). It is more appropriate, however, to model personal injury with state dependent utility functions. Arlen, "Liability for Injuries when Injurers as well as Victims Suffer Losses," 8 *Journal of Law, Economics and Organization* 411 - 426 (1992) shows that, when the risks are reciprocal, efficiency can be achieved.

Note that there may exist standards of care not equal to the efficient levels of care that induce the agents to choose the levels (x*, y*) that minimize (2).

[26]*The Costs of Accidents* argues that regimes of negligence or negligence with contributory negligence are too expensive to administer. Good social policy thus requires identifying the party who can best "bear the loss" regardless of the care choice made by the other party. Interests in deterrence point to identifying the "least cost avoider" as the appropriate bearer of the liability.

Diamond and Mirrlees seek to identify the conditions that identify the least cost avoider.[27] This task is simple when A(x,y) = A(x), B(x,y) = B(y), and D(x,y) =0. But when these conditions are not satisfied the identification of the least cost avoider becomes difficult.

5. Why was Brown's model more successful than Diamond's?

Brown's model was much more influential than Diamond's. As table 1 indicates, Brown's article received over than 3.5 times as many citations as Diamond's first article and over twice the number of citations as all three of Diamond's articles.[28] What explains this differential?

Brown's article of course was published first. Moreover, the difference between Brown's model and Diamond's model in single-activity accidents is very subtle (and not well-explained in Diamond's article). Diamond's essay therefore may, to an unsophisticated reader, appear a mere extension of Brown's initial model. Finally, Diamond's second and third articles were published in the Bell Journal of Economics, the level of technicality of which exceeded the competence of most lawyer-economists working at the time and they were not indexed on Lexis or Westlaw, increasingly common research tools for lawyers, and hence hard to find.[29]

More importantly, Brown's model is simpler, both formally an interpretively. It isolates a

[27]This article does not fully formalize the model implicit in *The Costs of Accidents* as it ignores Calabresi's secondary and tertiary costs. Calabresi's implicit model, that is, is even more complicated than the problem that Diamond and Mirrlees seek to solve.

[28]The factor of 2 understates the differential with Diamond's article as Diamond's articles were often cited together.

[29]Lexis, the Mead legal database, first became available in 1973. Westlaw became available in 1975. The *Journal of Legal Studies*, but not *The Bell Journal of Economics and Management Science* is indexed on Lexis and westlaw (confirm).

single externality that is fully transferable between the parties while Diamond's model posits a complex set of externalities, only some of which are transferable. It is straightforward to understand $A(x) = w_x x$ as Xavier's cost of adopting care level x; it is very unclear how to interpret A(x,y). Why would the costs of one agent vary with the choices of the other? Perhaps this difference merely reflects the simplicity of the analogy to a production function rather than one to a general equilibrium setting with externalities.

The formal simplicity of Brown's model made it easy to extend it: by introducing, for example, insurance markets or additional decision variables (such as activity levels) or multiple injurers. In part, this task is easy because analysts, following Brown, find the equilibria of the extended game. In part, the task is easy because, in Brown's model, there is a single, isolated externality.

The more complex models in Diamond are more difficult to extend and adapt in part because determining how care levels change as the standards of care change proves to be more complicated than finding the equilibria of the game and in part because the non-transferable externalities simply require more assumptions and restrictions to get results..

Perhaps more importantly, Brown's identification of a set of legal rules that induce efficient behavior fit the dominant understanding of the role of economic analysis of law: to rationalize doctrine as a set of rules that maximized social wealth. Posner developed this project in his *Economic Analysis of Law*, the first edition of which was published in 1973.

Diamond's series of articles, by contrast, set out increasingly complex and more abstract models. As noted earlier, Brown's model is a special case of the more general model in

"Accident Law and Resource Allocation," an observation that Diamond does not make. More significantly, Diamond primarily develops a project of policy analysis, not doctrinal analysis. His interest lies in identifying the best policy not in rationalizing extant doctrine.[30]

6. Brown and the Project of Doctrinal Analysis

One may understand Brown's project in several ways. First, one might understand the model as a form of conceptual analysis as it lays bare the structure of liability rules. Let us define Xavier's share of liability as $L_X(x,y; X,Y)$ and Yvonne's share of liability as $L_Y(x,y; X,Y)$. Then, Brown analyzes a classical liability rule as a rule L that satisfies the following:

$$L_X(x,y; X,Y), L_Y(x,y; X,Y) \varepsilon\{0,1\} \quad (4)$$

$$L_Y(x,y; X,Y) = 1 - L_X(x,y; X,Y) \quad (5)$$

Condition (4) just states that liability is all-or-nothing.[31] Condition (5) states simply that liability of both parties sums exactly to the loss incurred.

Through Brown's model, this analysis of the classical rule of civil liability displays an elegant simplicity that has proven extremely fertile to theorists in the economic analysis of law. Different specifications of the function p(x,y) allow its application to other bodies of doctrine,

[30]The economic analysis of law has shown little interest in developing the project that Diamond pursues – the development of a theory of the least cost avoider. Shavell's book "The Economic Analysis of Accident Law" provides an organized and subtle account of the literature. "Least cost avoider" has one entry in the index to an early passage that largely sets the analysis to one side. The book does not cite Diamond and Mirrlees, the only attempt to develop Calabresi's project.

[31]At least for "transferable external costs" or perhaps "measurable external costs." The all-or-nothing aspect of the rule is straightforward in Brown's model. In Diamond's formulation however, the externality is broader and gives rise to unmeasurable or non-transferable costs.

such as contract law,[32] takings law,[33] joint and several liability,[34] and restitution.[35] One might say, then, that Brown's model reveals the "unity" of the common law and the common element that creates this unity.[36] Specifically, liability rules succeed through what Cooter termed "double marginalization". The standard of care creates a knife-edge at the standard so that the non-liable party sees the cost of decreasing his care below the standard while the party bearing the costs obviously sees them.[37] The unification of various common law doctrines and the perspicuous way in which the notation reveals this elegant incentive structure qualifies as the primary insight of the model.[38]

Second, one might understand it, as Brown perhaps did, as a continuation of the "Coasean" project to show how decentralized institutions will, under appropriate conditions,

---

[32]Shavell?

[33]Blume and Rubinfeld?

[34]Kornhauser and Revesz "Sharing Damages among Multiple Tortfeasors," 98 *Yale Law Journal* 831-884 (1989) and "Apportioning Damages among Potentially Insolvent Actors," 19 *Journal of Legal Studies* 617 (1990)

[35]Dari-Mattiacci, "Negative Liability," 38 *Journal of Legal Studies* 21-59 (2009)

[36]Cooter "Unity in tort, contract, and Property: The Model of Precaution," 73 *California law Review* 1-51 (1985). Benoit and Kornhauser, "Game Theoretic Analysis of Legal Rules and Institutions," in Aumann and Hart (eds,) 3 *Handbook of Game Theory* 2229-2270 (2002) more explicitly sets out how each doctrinal area confronts a different specification of p(x,y).

[37]"Double marginalization" is a feature of conditions (4) and (5). At a workshop at Columbia Law School many years ago, William Vickery scoffed at the application of Brown's model to joint and several liability that many rules would induce efficient behavior, in particular one that charged both parties for the loss. This rule of course violates condition (5).

[38]It also raises a host of questions that have not been adequately examined. Though these liability rules share a common structure, they legal rules differ dramatically across doctrinal realms.

solve externality problems.[39] Liability rules are "decentralized" in the sense that they are applied *ex post* and require, in one sense, minimal government intervention: the simple determination of who bears the social loss.[40]

On this second account, the efficiency results would serve as benchmarks against which to assess the performance of the actual liability system. Understanding the deviations from the "pure liability rules" of the model would help us understand the actual liability system just as identifying the "transaction costs" that impede Coasean bargains helps to identify how law affects behavior.

Third, and related, Brown's project might "identify" the content of the law. On this account, Brown's model rationalizes doctrine.[41] The actual rules governing accidents are, on this account, social cost minimizing.

Finally, one could understand Brown's project as a preliminary step in the project of policy analysis. It seeks to explain how legal rules influence individual behavior.[42] This intent would have been furthered by investigating comparative statics as Diamond did; but such an

---

[39]An appendix to Brown's article argues that "Coasean" bargaining over the legal rules would lead to a negligence rule with standards set optimally.

[40]The claim that liability rules are somehow less "centralized" than a Pigovian tax is exaggerated. It is true that the court simply "adjudicates" but the sheriff stands ready to enforce the judgment just as she stands ready to collect the Pigovian tax should the agent fail to pay. Moreover, the court, like the tax authority, must determine the appropriate size of the tax or liability payment. It is not obvious that it is more decentralized to assess the size of the payment *ex post*, case-by-case, than to assess it *ex ante* as an expected value.

[41]Cooter and Kraus contend more strongly that the requirement of efficiency in these areas serves as part of the rule of recognition and is thus constitutive of the law.

[42]I discuss this understanding of the project at greater length in the next section.

investigation would have made the article more complex and hence less accessible to lawyers.[43]

Unfortunately, it is hard to see how Brown's model can serve either as a benchmark or as a rationalization of extant doctrine in any jurisdiction.

Consider now the use of Brown's model to rationalize legal doctrines governing tort law. The project of doctrinal analysis contends that, in any common law jurisdiction, the legal rules are "efficient." Doctrinal analysis thus apparently makes an empirical claim about the efficiency of the behavior induced by the legal rules governing accident law. Yet the literature contains very few, if any, empirical investigations into behavior. Indeed, such investigations would be extremely difficult to conduct.[44] A regime of negligence with contributory negligence, for instance, has myriad effects on primary behavior; it determines not only the extent to which individuals take care but also the nature and level of the activities they undertake.

The claim of efficiency then presumably rests on the conclusions of something like Brown's model that proves, under specified circumstances, negligence rules with the standards of care set appropriately induce agents to adopt the social cost-minimizing levels of care.[45] But Brown's model, as most models, is very spare relative to the complexity of the world. More

---

[43]A more extensive sociological inquiry than undertaken here would investigate any differences across the disciplines of law and economics that the two articles received. Brown's article is much more accessible to lawyers and did, in fact, have a larger impact (as measured by citations) than Diamond's articles. Two of Diamond's articles were published in the Bell Journal which would have been a foreign venue for legal academics to visit.

[44]Posner's "A Theory of Negligence" includes an empirical study. But Posner studies case law not the primary behavior of individuals and it is this primary behavior on which the efficiency of the tort law rests. The set of appellate cases decided represents an extremely biased sample of the behaviors induced by the legal regime.

[45]It certainly doesn't rest on empirical evidence that legal rules are in fact efficient.

troubling, the efficiency of these equilibria are not robust to many perturbations of the underlying, often implicit, assumptions of the model.

To begin, recall the structure of analysis in Brown. Brown sets out a simple model and then proves theorems of the form: "Under a legal regime of negligence with contributory negligence, agents choose the cost-minimizing levels (x*, y*) of care when the standards of care are set at X = x* and Y = Y*." What does this theorem tell us about the behavior of agents (such as drivers, pedestrians, and bicyclists) undertaking risky activities in the real world? We might address this question in at least two ways. First, one might ask whether and how the agents reach this equilibrium. This question raises both theoretical and empirical issues. Second, and related, one might consider how robust the theoretical results are to perturbations.

Brown presents a one-shot game. It is unclear whether the agents will, in fact, identify the Nash equilibrium of the game. The very limited empirical evidence on this question is at best mixed. Wittman et al. study two-actor accidents and find that, under negligence with contributory negligence, subjects in their experiments were negligent. This finding is consistent with the more ambiguous finding in Kornhauser and Schotter which suggests that under a rule of negligence the subjects who are the default bearers of liability may take too little care.[46] In these

[46]Wittman, Friedman, Crevier, and Braskin, "Learning Liability Rules," 26 *Journal of Legal Studies* 145-62 (1997). Kornhauser and Schotter, "An Experimental Study of Two Actor Accidents," NYU C.V. Starr Center working paper 91-60 (1991) finds a statistically insignificant difference but under precaution is consistent with their study of single activity accidents. Kornhauser and Schotter, "An Experimental Study of Single-Actor Accidents," 19 *Journal of Legal Studies* 203 (1990) in which an agent facing strict liability takes too little care. (When a regime of negligence governs a two-actor accident, the default bearer of liability faces strict liability when playing against a rational agent.) For a survey see Halbersberg and Guttel, "Behavioral Economics and Tort Law," in Zamir and Teichman (eds.) *The Oxford Handbook of Behavioral Economics and Law* (2014) or Sullivan and Holt, "Experimental Economics and the

experiments, of course, the subjects play a game in which each chooses a number rather than adopt a care level in an activity in which they are engaged.

Moreover, in what way does the existence of an equilibrium *explain* a phenomenon. The existence of the Nash equilibrium of course suggests that efficiency is *possible* but it hardly shows that efficiency is *realized*. But what reasons do we have to believe that behavior in the world corresponds to the behavior in the model? Our confidence might be higher if the conclusions of the model were robust to perturbations in the underlying assumptions. But the conclusions are not robust to these perturbations.

Table 2 categorizes and lists a set of key assumptions underlying Brown's (and Diamond's) model. It is not exhaustive[47] but captures a set of central assumptions about the agents, their choice sets, and the legal and non-legal environments in which they act.

Table 2
Implicit Assumptions of the Model(s)

Type of Assumption	Assumption
About agents	Economically rational Narrowly self-interested preferences Risk Neutral Perfect Information Fully solvent

Law," in Parisi, (ed.) 1 *The Oxford handbook of Economics and the Law* (2014).

Finally, these experiments have limited, if any, external validity. Extrapolating from choosing numbers in a laboratory to driving on the highway is risky.

[47]It ignores for example assumptions about the convexity of p(x,y) for Brown (and, for Diamond, the convexity of A, B, C and D.)

Agent's Choice Set	"Care" only (so fixed activity level) "Care" is one-dimensional
Policymaker's Choice Set	A "fixed standard" (i.e., a "rule")
Non-Legal Environment	External costs are fully transferable (Brown) Uniform costs (within agents engaged in same activity) No Insurance Market
Legal Environment	Complete Information Litigation is Costless and perfectly accurate All accidents result in litigation No settlement Legal centralism Tort law exclusivity

Subsequent research has investigated the consequences of weakening many of the assumptions listed in the table. In virtually every instance, relaxing the assumption eliminates the result that setting the standards of care equal to the cost minimizing levels of care induces efficient behavior.

Consider first a problem of interpretation. The model assumes that the court sets the standards of care at a specific level of care; i.e., the court announces rules. But accident law actually uses the "reasonable person" standard that requires agents to act as an ordinary, reasonable person would under the circumstances. Economic analysts of accident law typically rely on Judge Learned Hand's analysis in United States v. Carroll towing Co.,[48] In that case,

[48]159 F.2d 169 (2d Cir. 1947)

Learned Hand stated that the reasonable person would take care as long as B < PL, where B was the "burden" imposed by taking care and PL the expected harm. Treating this condition as a marginal condition would indeed yield the relevant economic test.

Courts, however, do not typically understand the reasonable person standard as Hand did. The fact finder determines whether an agent exercised reasonable care.[49] In the United States, the typical fact-finder is the jury to which the judge provides instructions on the law. Only in one state does the instruction set out something like Hand's cost-benefit analysis and only four others even rely on the concept of a foreseeable, but unreasonable, risk.[50]

Second, consider the assumptions about the non-legal environment. Diamond's second article immediately showed how relaxing the assumption that all external costs are fully transferable. Obviously, once external costs are not fully transferable, efficiency cannot be achieved. In accidents that cause personal of injury, of course, some external costs are not fully transferable and we can hardly expect the liability rules to generate efficiency.[51]

---

[49]As reasonable care is a question of fact, appellate review is limited. Consequently, different juries faced with the same facts need not reach the same conclusion and each jury verdict would stand. This circumstance can easily arise when a single action injures multiple individuals.

Jury discretion thus implies that the standard of care is uncertain, contrary to the assumption in Brown's (and Diamond's) models. We know that, under uncertainty, setting the standards at the efficient level of care does not induce efficient behavior. See Shavell,

[50] Kelley and Wendt, "What Judges Tell Juries about Negligence," 77 *Chicago-Kent Law Review* 587, 618-9 (2002).

[51]Diamond's model does not obviously capture personal injury; he models the non-transferable costs as utilities A(x,y) and B(x,y) which depend on the levels of care that the agents adopt but not on whether an accident is realized. It is more natural, however, to model personal injury with state-dependent utility functions. In one state, where no accident occurs, the agent suffers no personal injury. In the other state, an accident does occur and the agent suffers

Both Brown and Diamond implicitly assume "legal centralism" and "tort law exclusivity." "Legal centralism" assumes that law has displaced all other normative systems; the legal norm is the only norm that creates incentives. "Tort law exclusivity" assumes that the negligence/contributory negligence regime is the only operative legal norm governing the conduct. Neither of these assumptions, of course, accurately describes the situation faced by agents in the real world. Agents face both *ex ante* regulation of their conduct and *ex post* regulation, typically criminal regulation. Many negligent actions, at least in the context of automobile accidents, are also subject to criminal or administrative fines or other penalties. Similarly, negligent conduct is often governed by non-legal, as well as legal, norms.

The many extensions of the model show how fragile the model's results are. Diamond's 1974 article established that clearly. Brown's model can be understood as a special case of the more general model set out in Diamond (1974). It is clear that a negligence regime (or a negligence with contributory negligence will not in general yield the social cost minimizing levels of care when standards of care are set at (x*, y*).

7. Diamond and the Project of Policy Analysis

Diamond and Mirrlees explicitly characterize their project on the least cost avoider as

---

personal injury. Arlen adopts this formulation in "Liability for Physical Infury When Injurers as Well as Victims Suffer Losses," 8 *Journal of Law Economics and Organization* 411-426 (1992) shows that in two activity accidents in which the agents face reciprocal risks of personal injury a rule of strict liability with contributory negligence will induce the agents to adopt efficient levels of care when the standard is set correctly. But the efficient legal rule here does not correspond to any known tort rule. First, each party must face an identical damage amount that is not tied in any obvious way to the actual damages that the agents suffer. (There is no reason to think that a pedestrian and a motorist involved in an accident suffer the same degree of "pain and suffering" let alone the same medical costs.

policy analysis. In an economy with externalities, they seek to identify to which of two parties it is best to assign liability for transferable external costs. This policy exercise is an exercise in second-best analysis. The first-best outcome is not achievable. They thus compare the two equilibria on welfarist grounds to identify the best cost bearer. In the course of this exercise they provide a precise specification of Calabresi's least cost avoider and then, in a few limited circumstances, state conditions that identify the appropriate assignment of liability.

Diamond's two earlier articles also reflect his interest in policy analysis. Diamond's interest does not lie in finding efficient equilibria. Rather he seeks to understand how equilibrium behavior changes as the standards of care change. This exercise in comparative statics requires extended, complex analysis. This complexity made his models less accessible. Indeed, his models seem unnecessarily cluttered.[52]

Similarly, the generality of Diamond's model made them less interpretively transparent. It was thus difficult to extend them and to adapt them to other doctrinal areas. In the first two articles, Diamond provides little motivation or discussion of the formal model. Its applicability to the regulation of real world accidents is not very clear though he does carefully note the many idealizations on which the model relies.

Diamond and Mirrlees, by contrast, make considerable effort to interpret and apply their model. They do so in two distinct ways. They provide two simple examples to illustrate the application of the model and, in introducing the formalism and the results, they are attentive to

[52]For example, writing $p(x,y)A$ as $n\pi(x,y)C(x,y)$ merely complicates the analysis without obviously adding any insight. It would be simpler to write, this term, as Diamond and Mirrlees do, as $C(x,y)$.

problems of measurement and comparability of the functional forms.

Consider measurement problems first. They begin by assuming that the care taken by each agent are measurable in the same units. They then derive similar results under a weaker assumption. They are, however, perhaps less attentive than they might be to the measurement and comparability of the non-transferable external costs. After all, the non-transferability of the costs may derive from their difficulty of measurement and comparability.

Consider now the two simple examples that they provide in their concluding observations. They use a simple truck-train example to illustrate physical and social correlates of the abstract model they have analyzed. The example illustrates well how either the presence of third-party externalities or non-transferable externalities to one of the parties complicate the analysis. Similarly, the desert rescue example reveals how their model bears on issues normally addressed by contract law rather than tort law.

The examples and the measurability concerns underline the distance between the model and the problem confronted by the policymaker. As they note, they largely ignore problems created by insurance markets and posed by the existence of parties not involved in the accident that can alter the probability and the effects of accidents. But, in fact, table 2 identifies not just the assumptions of Brown's model but also those of Diamond's models. It is worth noting, however, that, while we know that the efficient equilibrium is not robust to the weakening of these assumptions, we don't know whether the comparative statics are robust to weakening these assumptions.

Of course, Diamond wants to identify the best policy given actual constraints. How does

the second-best analysis he provides assist in policymaking in a third-, fourth- or fifth-best world? As Diamond and Mirrlees point out, their theorems identify a set of empirical questions the policymaker must confront in their second-best world. Answering these questions would allow direct application of their theorems to the idealized world of the model.

As noted above, however, the real world differs dramatically from the idealized world. These models can at best guide thought about policymaking.8. Concluding Remarks

The early 1970s saw the rapid emergence and growth of formal models in the economic analysis of law.[53] Brown's model played a central role in that growth. Its significance in that growth was much greater, I argue, than a set of parallel, and related, models introduced by Diamond at virtually the same time. This essay attempts to illuminate the different impact of these models through an investigation of how and what models teach.

The essay argues that Brown's model prevailed for several reasons. First, it was both formally simpler and interpretively more transparent. The model isolates in a very perspicuous manner how a liability rule can control an externality. The formal simplicity facilitated extending

[53]To be precise the first formal work seems to have been a remarkable series of four papers published between 1968 and 1970 by Robert Birmingham on contract law,: "Breach of Contract, Damage Measures, and Economic Efficiency," 24 *Rutgers Law Review* 273 (1970), "Damage Measures and Economic Rationality: The Geometry of Contract Law," 1969 *Duke Law Journal* 49-71, "The Growth of the Law: Decision Theory and the Doctrine of Consideration," 55 *Archives for Philosophy of Law and Social Philosophy* 467-491 (1969), and."Legal and Moral Duty in Game Theory: Common Law Contract and Chinese Analogies," 18 *Buffalo Law Review* 99 (1968). Birmingham's models were not particularly generative; a few articles in the 1970s cite them and deploy similar methods but the canonical model of contract damages appears in Shavell, "Damage Measures for Breach of Contract," 11 *Bell Journal of Economics* 466-490 (1980).

In this instance, Shavell's model is more abstract and more adaptable than the variety of simpler, but somewhat ungainly, approaches that Birmingham adopted. Moreover, all of Birmingham's articles appear in law reviews where economists were unlikely to encounter them.

the model by relaxing various assumptions and adapting the model to other doctrinal contexts. Both the analogy to the production function and the formal simplicity of the model contributed to its interpretive transparency that connected to the model to a context familiar to lawyers.

Second, the transparency of the interpretation of Brown's model revealed the unity of the common law. Brown sought to model tort law but the model in fact also captured essential elements of contract law, property law, and restitution. Moreover, the model allows one to glimpse the differences among the doctrinal subjects; the specification of the function p(x,y) reveals some of the differences among the subjects. Laying bare the structure of the common law perhaps constitutes the most significant lesson the model taught.

Third, and finally, Brown's model and formulation of his project apparently advanced doctrinal analysis, the claim that common law rules were in fact efficient or social cost minimizing. This apparent compatibility derived from Brown's focus on equilibrium analysis rather than comparative statics.[54] The extensions of Brown's model, however, suggest that the project of doctrinal analysis is misguided. These extensions typically show that the model's efficient equilibrium is not robust to almost any weakening of central assumptions. While Brown's model proved that a regime of negligence with contributory negligence that sends the standards of care at the cost-minimizing levels of care minimizes social costs in a simple world, actual tort law functions in a more complex world in which this regime probably is not efficient.

Diamond's models, by contrast, advanced the project of policy analysis. He focused on

[54]Arguably the equilibrium analysis promoted both the simplicity and the transparency of the model. Deriving comparative static results from the model requires significantly more work and complexity, as Diamond's models show.

comparing equilibria (on welfare criteria) rather than simply finding them. This focus made his models more complex but more useful to the policymaker who must generally chooses among a variety of imperfect rules. Diamond and Mirrlees illustrates this task best as, in this article, the authors explicitly focus on a restricted class of two rules, neither of which will, in general, be efficient.