Law and Economics: Intellectual Arbitrage

Randal C. Picker

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An arbitrage opportunity is an investment strategy that guarantees a positive payoff. A simple example of arbitrage is the opportunity to borrow and lend without cost at two different fixed rates of interest: borrow at five percent, lend at ten percent, pocket the spread. Another is the ability to buy stock for ten dollars per share and sell it for twelve dollars. Arbitrage is the great dream: a sure-fire way of making money. The 1980s saw the rise of arbitragers: individuals and firms devoted to finding fleeting disparities in prices across markets. Arbitragers jumped in and eventually brought prices into line.[1]

However often arbitrage opportunities arise in financial markets, sure-fire arbitrage opportunities in academia are largely nonexistent. Nonetheless, put more broadly, intellectual arbitrage[2]—meaning transplanting ideas from one field to a second field—has become a standard move for any card-carrying member of the interdisciplinary movement. In law, intellectual arbitrage has proven, and surely will remain, a relatively easy route to the academic coin of the realm—namely, distinguished publications and large numbers of citations. If anything, the trend seems to be accelerating with the rise of student publications de-

1. For a standard definition, see the description of arbitrage in PHILIP H. DYDVIG & STEVEN A. ROSS, THE NEW PALGRAVE: A DICTIONARY OF ECONOMICS 100-06 (John Eatwell et al. eds., 1987).

2. The phrase intellectual arbitrage is not mine. I have seen it in print in only one place. *See* Michael A. Fitts, *Can Ignorance Be Bliss? Imperfect Information as a Positive Influence in Political Institutions*, 88 MICH. L. REV. 917, 981 (1990) (describing article as "intellectual arbitrage between law and political science"). I believe I first heard the term from Richard Epstein sometime prior to having seen the Fitts article.

voted solely to interdisciplinary work.[3] Whether this is a good thing can be questioned[4] as the distance between the professorate and honest-to-god attorneys grows each time we say "hermeneutics" or "pareto improvement" or any of the other now-standard terms that have crossed over from other disciplines into the legal academic's vocabulary. For the present purpose of this Symposium on interdisciplinary work, I suspend judgment on the merits of intellectual arbitrage and instead focus on its prospects.

Law and economics was an early "law and . . . ." Its roots run fairly deep, perhaps as far back as 1932,[5] though in many ways its beginnings can be traced to Ronald Coase's *The Problem of Social Cost*, published in 1960.[6] In its statement awarding to Coase the 1991 Bank of Sweden Prize in Economic Sciences in Memory of Alfred Nobel, the Royal Swedish Academy of Sciences cited this article as "the impetus for developing the new discipline of 'law and economics' and, in prolongation, for renewal of many aspects of legal science."[7] Coase's Nobel Prize coincided with other evidence of the discipline's intellectual maturity. The American Law and Economics Association held its first annual meeting also in 1991 and has now had three generally well-attended annual meetings. We now approach the twentieth anniversary of Richard Posner's *Economic Analysis of Law* which is in its fourth edition.[8]

This sounds like maturity—a euphemism for middle-aged paunch—and, perhaps, diminished opportunities. Not so. Indeed, the time seems right to move from the first-generation of law and economics to the next generation. What is at stake is what that second generation will look like. Economics continues to change, in many areas quite rapidly. I am unaware of any definitive measure of the rate of change of ideas in a field and, unfortunately, casual looks can be deceiving. As the old joke goes,

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3. For examples, refer to the *Southern California Interdisciplinary Law Journal* and *The University of Chicago Roundtable*.

4. This trend has been questioned, perhaps most forcefully, by former academic Judge Harry Edwards. *See* Harry T. Edwards, *The Growing Disjunction Between Legal Education and the Legal Profession*, 91 MICH. L. REV. 34 (1992) (discussing law schools' emphasis on theory rather than practice). Judge Edwards's article clearly struck a nerve. *See, e.g.*, Symposium, *Legal Education*, 91 MICH. L. REV. 1921 (1993).

5. Edmund W. Kitch, *The Fire of Truth: A Remembrance of Law and Economics at Chicago, 1932-1970*, 26 J.L. & ECON. 163 (1983) (transcribing discussion on history of law and economics, among Kitch, Milton Friedman, George A. Stigler, Richard A. Posner, and Robert H. Bork).

6. R.H. Coase, *The Problem of Social Cost*, 3 J.L. & ECON. 1 (1960). .

7. The Royal Swedish Academy of Sciences, Information: The Sveriges Riksbank (Bank of Sweden) Prize in Economic Sciences in Memory of Alfred Nobel (Oct. 15, 1991) (unpublished press release, on file with *Loyola of Los Angeles Law Review*).

8. RICHARD A. POSNER, ECONOMIC ANALYSIS OF LAW (4th ed. 1992).

an alumnus returned to his alma mater after a twenty-year absence. He was surprised to see that the current group of students was taking precisely the same tests he had struggled through in his student days. He commented to the professor that he would have thought that in the intervening period, new bits of knowledge would have come to the fore, but instead the students were doing the very tests he had taken. The professor's response: "Oh, the questions are the same, it's the answers we've changed."

Even in a field as well-considered as classical microeconomics, new ideas emerge. New techniques arise, in some cases resulting in new questions, but often allowing old questions to be explored with new fervor. When this happens—when the economist acquires a new tool—our intellectual arbitragers stand ready to import it into legal analysis. I am here to report on one such tool, game theory. This tool is starting to cross over and has created an opportunity that is now being realized in law and economics. In this Essay, I make no effort to describe the evolving literature and in fact will cite very little. Instead, I try to lay out some of the basic notions of game theory and how they, in turn, may allow us to improve our understanding of law.

I. GAME THEORY AND STRATEGIC BEHAVIOR

As a discipline, law and economics advanced on the strong back of classical microeconomics. Individual decision makers maximized utility or profits subject to constraints. These individuals were treated either as price takers in competitive settings or price setters in monopolies. They were also perfectly informed. A sizable and largely successful academic legal literature grew out of taking first derivatives and ruthlessly applying the discipline of the microeconomist's marginal analysis to a vast array of legal problems.[9]

The last twenty years have seen a major shift in the fundamental methodological tools used by microeconomic theorists. Game theory has emerged to augment the standard, polar approaches of pure competition and monopoly. In a competitive setting, individuals or firms are seen as having no real decisions to make. Prices are given, and individuals and firms are price takers. The other production paradigm, monopoly, treats the monopolist as a price setter for a given demand curve. In a game-

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9. A sample of well-known textbooks and research monographs makes the point. *See, e.g.*, ROBERT COOTER & THOMAS ULEN, LAW AND ECONOMICS (1988); WILLIAM M. LANDES & RICHARD A. POSNER, THE ECONOMIC STRUCTURE OF TORT LAW (1987); A. MITCHELL POLINSKY, INTRODUCTION TO LAW AND ECONOMICS (2d ed. 1989); STEVEN SHAVELL, ECONOMIC ANALYSIS OF ACCIDENT LAW (1987).

theoretic setting, rational actors must worry about the actions of others—this is the fundamental strategic interdependence that game theory addresses. Other settings lack the back-and-forth quality that characterizes strategic settings.

Game theory sounds like fun—visions run the gamut from Candyland to Monopoly. A definition might be useful; as a rough cut, try: *Game theory is a set of tools and a language for describing and predicting strategic behavior.* Later, I discuss what these tools are and how to apply them. But first, I focus on the core concept in the definition, strategic behavior. Strategic settings are situations in which one person would like to take into account how a second person will behave in making a decision, and the second person would prefer to do likewise. Strategic settings typically involve two or more decision makers, and the possibility of connecting, or a desire to link, one decision with a second decision.

Consider the airlines industry. Whether Northwest will cut fares may depend on how American and United will respond, and the same reasoning holds true for American and United. Indeed, Northwest recently filed suit against American claiming that American's introduction of a new pricing schedule was part of a scheme of predatory pricing designed to put Northwest out of business.[10] Oligopolistic industries— airlines, computer microprocessors, or operating systems, for example— are natural settings for strategic interactions.

But so is a country road. I have risen for an early-morning walk. I would like to enjoy the view, take in the scenery, and generally ignore the cars going by me. You unfortunately are driving your new Mazda Miata. You want to see how the car handles by testing how it drives through turns and how it accelerates. If I knew that you were driving like a maniac, I would want to take that into account in deciding whether to pay much attention to the road. If you knew that I was soaking in the countryside and ignoring the road, you would want to take that into account as well. Our behavioral decisions are intertwined, and we need to take that fact into account when we seek to predict likely outcomes. The legal system should take this into account as well when it establishes antitrust laws for oligopolistic industries or a torts scheme for ordinary accidents.

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10. *See* Bridget O'Brian, *Antitrust Dogfight: Predatory Pricing Issue Is Due to Be Taken Up in American Air's Trial*, WALL ST. J., July 12, 1993, at A1.

II. NORMAL FORM GAMES, DOMINANT STRATEGIES AND THE HIDDEN ROLE OF LAW

A. The Prisoner's Dilemma

The best known game is the Prisoner's Dilemma. I go through the analysis to make clear how much game theory has already crossed over as well as to establish some terminology. I then move on to more natural settings. So consider the following "game":

	Prisoner 2 Silent	Prisoner 2 Confess
Prisoner 1 Silent	-2, -2	-10, 0
Prisoner 1 Confess	0, -10	-6, -6

Payoffs: (Prisoner 1, Prisoner 2)

FIGURE 1: PRISONER'S DILEMMA

Here is the story that this game is trying to capture. We have two prisoners, or, more generally, two players. They both have committed a serious crime, but the district attorney cannot convict either one of them without extracting at least one confession. The district attorney, however, can convict them both on a lesser offense without the cooperation of either. The district attorney tells each prisoner that if neither confesses, they will both be convicted for the lesser offense. Each will go to prison for two years. This outcome is represented in the upper left cell.

If, however, one of the prisoners confesses and the other does not, the prisoner who confesses will go free and the other will be tried for the serious crime and given the maximum penalty of ten years in prison. This applies to both prisoners and is represented in the off-diagonal cells. Finally, if both confess, the district attorney will prosecute both for the serious crime, but not ask for the maximum penalty. They will both go to prison for six years. This is the final cell, the lower right cell.

This is a *normal form game*. We have identified the players, our two prisoners; the choices available to them, or their strategies, here, to be silent or confess; and the outcomes associated with the four different strategy pairs. The layout here in the two-by-two matrix is the standard way of representing this normal form game.

Now the solution of the game. Each prisoner wants to minimize time spent behind bars and has no other goal. Moreover, each is indifferent to how much time the other spends in prison. I ignore the possibility of altruism or spite. I also ignore the reputational issues that might arise

from being known as a snitch or fear of reprisal from confessing. Finally, the two prisoners have no way of communicating with each other. Each must decide without knowing what the other will do.

This is a game in which each prisoner has a *strictly dominant strategy*. Each is better off confessing regardless of what the other does. One can solve the game by recognizing that each prisoner is likely to reason in the following way: "If the other prisoner has decided to keep silent, I am better off confessing. That way I spend no time behind bars at all, rather than two years. What about the other possibility? If the other prisoner confesses, I am also better off confessing. As bad as serving a six-year sentence might be, serving a ten-year sentence is worse. No matter what the other person does, I am better off confessing. No prison is better than two years, and six years is better than ten years." Because both prisoners will likely engage in this reasoning, both are likely to confess.

The outcome—both prisoners confess—seems counterintuitive at first because the prisoners would have been better off if both had remained silent. But this result follows once we assume that we have structured the payoffs correctly. Even if each prisoner erroneously believed that the other was altruistic and would confess, we would still have the same outcome, *given our assumption that the prisoners care only for themselves*. If a prisoner believes the other will remain silent, confessing is a way of avoiding prison altogether, the best outcome of all.[11] The result is not at all odd once one recognizes that the prisoners lack a means of committing themselves to remaining silent. As long as the two prisoners cannot reach any agreement with each other and as long as their only concern is time spent in prison—and not, let us say, their reputations as finks—their individual interest will lead them to confess, even though they are jointly better off by remaining silent.

The power of the Prisoner's Dilemma comes from the incongruence between private benefit and the collective good. Individually, rational decision making leads to collective disaster. The Prisoner's Dilemma is thus often seen as one of the main theoretical justifications for government intrusion into private decision making.[12] Legislation almost appears attractive given the collective disaster that results from individual decision making in the dilemma.

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11. Again, if the prisoners cared about something in addition to the length of time spent in jail, we have specified the payoffs incorrectly. The premise of the game is that the players are both selfish.

12. *See, e.g.*, CASS R. SUNSTEIN, AFTER THE RIGHTS REVOLUTION: RECONCEIVING THE REGULATORY STATE 49-51 (1990).

I say "almost" for two reasons. First, the existence of private failure tells us nothing about whether government decision making enjoys a comparative advantage over private decision making. The Churchill line about democracy—"Democracy is the worst form of Government except all those other forms that have been tried from time to time"—may apply here as well. We need to know much more about the quality of government decision making before we can summarily abandon private decision making. The second reason for being cautious about relying on a simple game-theoretic model such as the Prisoner's Dilemma to justify legal intervention will require more hardware, so I return to it at the end of this Essay.

B. An Example from the Law of Torts

Many legal settings can be represented as normal form games and solved by identifying dominant strategies. Consider an accident on a country road involving a motorist and a pedestrian. The likelihood of an accident turns both on how much care the motorist uses in driving and how much care the pedestrian uses in crossing the street. We do not expect the motorist to drive so slowly that there never is any possibility of hitting a pedestrian. Nor do we insist that the pedestrian cross only when there is no car in sight. We want them both to take sensible precautions. If both act reasonably, the chances of an accident as well as the inconvenience to both parties are minimized. If they could bargain with each other, we would expect that each would agree to act in this way. The problem arises, of course, because the two are strangers and they cannot communicate with each other. The motorist and the pedestrian both recognize that the other's actions influence what will happen. That basic fact must be recognized to conduct a sensible analysis of the situation. Hence, game theory is the right tool for this problem.

To jump right in, consider the following game:

	Motorist	
	No Care	Due Care
No Care Pedestrian	-100, 0	-100, -10
Due Care	-110, 0	-20, -10

Payoffs: (Pedestrian, Motorist)

FIGURE 2: NO REALLOCATION LAW

Here are the stylized facts that this game is seeking to represent. If an accident takes place between the motorist and the pedestrian, the motorist and her car will not be hurt, but the pedestrian will of course suffer harm. Assume that we can represent the harm to the pedestrian as a dollar amount, set at $100. Both the motorist and the pedestrian decide on how much care to take. Assume that they each choose between taking "no care" and "due care." Representing the decision of how much care to take as a binary choice oversimplifies greatly, but it is the natural place to start. Assume that it costs nothing to exercise "no care" but costs ten dollars to exercise "due care."[13] We also need to know how the care choices relate to the probability of an accident occurring. Assume that the accident is certain to happen unless both the motorist and the pedestrian exercise "due care," but that there is still a one-in-ten chance of an accident occurring even if both exercise "due care."

So far, we have set out the brute facts of nature: the choices available to our players, the motorist and the pedestrian, or what a game theorist would call the strategies of the players, and the physical consequences associated with those strategies; that is, whether an accident takes place and the resulting harm. To fully specify this game, we need one more crucial item: We need to know the legal rule for allocating the harms of an accident. The problem of strategic behavior that the legal analyst faces is a simple problem of simultaneous decision making. The amount of care that the motorist and pedestrian each take would turn on the amount of care each expects the other to take. The amount of care that each takes will turn to some degree on the legal rule that is in place—that is, when and to what extent the motorist will have to pay damages to the pedestrian in the event of an accident. The first question for the legal analyst concerns the effect of changes in the legal rule on the behavior of the parties. Start with a rule of no liability, or of letting the parties bear their own losses. In this case, if an accident occurs, the motorist is not harmed and the pedestrian is harmed; the legal rule of no liability does not reallocate any of the harm by having the motorist pay damages.

We can now explain the game in figure 2 and determine how to solve it. In a legal regime of no liability, the motorist would enjoy a payoff of zero dollars and the pedestrian a payoff of minus $100 if neither exercises care. The cost of "no care" is zero; an accident is certain to happen, and the accident harms the pedestrian to the tune of $100. If

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13. "Due care" is really a legal term for a physical level of care. Consistent with the convention, "due care" is the level of care that minimizes the total expected costs of the accident.

both exercise care, the motorist would receive a payoff of minus ten dollars and the pedestrian a payoff of minus twenty dollars.[14] If the motorist exercises care and the pedestrian does not, the motorist receives a payoff of minus ten dollars (the cost of taking care) and the pedestrian a payoff of minus $100 (the cost of the accident, which by assumption is certain to arise unless both take care). Finally, if the motorist does not take care and the pedestrian does, the motorist has a payoff of zero dollars and the pedestrian a payoff of minus $110 (the pedestrian invests ten dollars in taking care and still suffers a $100 injury).

What is the likely outcome of this game? In this model, taking care costs the motorist ten dollars and provides no benefit to the motorist in return. The motorist always does better by not taking care than by taking care. We can predict the motorist's likely choice of strategy because there is a single strategy—"no care"—that, in the context of this model, is better for the motorist no matter what choice the pedestrian makes. In the language of game theory, this is a *dominant strategy*—really a *strictly* dominant strategy. Conversely, a strategy which is always worse than another strategy, regardless of what the other player does, is a *dominated strategy*. In figure 2, "due care" is a dominated strategy for the motorist. We should predict—as we did in analyzing the Prisoner's Dilemma— that a player will embrace a dominant strategy wherever possible and will not embrace any strategy that is dominated by another.

This idea by itself, however, tells us only what the motorist is likely to do in this model. We cannot use this concept to predict the pedestrian's behavior. Neither of the strategies available to the pedestrian is dominated by the other. It makes sense for the pedestrian not to take care when the motorist does not and to take care when the motorist does. The pedestrian lacks a dominant strategy because either course of action could be better or worse than the other depending upon what the motorist does.

Note that, in this regard, this game differs from the Prisoner's Dilemma, in which both players had a dominant strategy. To predict the pedestrian's behavior, we need to take the idea that players play dominant strategies one step further. Not only will a player likely adopt a strictly dominant strategy, but a player will predict that the other player is likely to adopt such a strategy and will act accordingly. We can predict, in other words, that the pedestrian will choose a strategy based on

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14. The pedestrian invests $10 in care and, assuming the pedestrian is risk-neutral, still faces $10 in expected accident costs, a one-in-ten chance of a $100 accident.

the idea that the motorist will not choose a strategy that is strictly domi-
nated by another.

This idea travels under the name of *iterated dominance* and allows
us to solve this game. The pedestrian should understand that the motor-
ist has a dominant strategy—play "no care"—and therefore the pedes-
trian should play "no care" as well. Given that the motorist plays "no
care," the payoff to the pedestrian from playing "due care" is minus $110
and that from playing "no care" is minus $100, and therefore the pedes-
trian should play "no care" as well.[15] Thus, neither player exercises care.
Note that to reach this solution, we proceeded iteratively. We first iden-
tified the strategy that the motorist would play using dominance argu-
ments—this is the first iteration—and we next identified the pedestrian's
strategy *given* the motorist's strategy as determined in the first stage of
the argument—this is the second iteration. This is the logic of iterated
dominance.

This extension of the idea that dominated strategies are not played
requires us to make a further assumption about the rationality of the
players. Players not only act rationally and do the best they can given
their preferences, but they also believe that others act rationally as well
and do the best they can given their preferences. This solution concept
seems plausible if the number of iterations is small. After all, most peo-
ple act rationally most of the time, and we can choose our own actions in
anticipation that they will act this way. If we accept this solution con-
cept, we can solve the game in figure 2. The pedestrian will not exercise
care because the pedestrian will believe that the motorist will not exercise
care and, in that event, the pedestrian, under our assumptions, is better
off not exercising care. We cannot, however, make this prediction as
confidently as we can predict the motorist's behavior. The solution to
the game turns not only on the motorist acting in a way that advances
her self-interest, but also on the pedestrian anticipating that the motorist
will in fact act in this way.

You might think that these results are specific to the particular
numbers set forth in figure 2. The specific result is, though the result that
matters is not. In the example in figure 2, the pedestrian chooses to exer-
cise no care when the motorist exercises no care. That outcome is tied
directly to the particular probability function for accidents, which makes
it worthless for one player to exercise any care if the other player is exer-
cising no care. In general—meaning for different probability functions

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15. Recall that the accident is certain to happen unless both players play "due care"; once
the motorist will not, the pedestrian is better off by not wasting any money on care.

for accidents—the pedestrian might choose more or less than "due care."
The general result is the result that matters: Under a rule of no realloca-
tion of losses and where any harm from the accident will be borne by the
pedestrian, the motorist lacks an appropriate incentive to take care. In-
deed, as shown above—and this is a general result—exercising "no care"
is a dominant strategy.

Thus, playing under a rule of no liability puts us far from the social
goal of having both players exercise due care. This result is hardly star-
tling. To say that the strategy of taking "due care" is dominated by an-
other strategy of taking less than due care restates in the language of
game theory a familiar insight from law and economics. That is, the
insight that in a world in which losses are not reallocated, parties tend to
take less than due care because they do not fully internalize the costs of
their actions.[16] The motorist enjoys all the benefits of driving fast, but
does not bear all the costs (the danger of injuring a pedestrian or another
motorist). By capturing the problem of the pedestrian and the motorist
in the form of a two-by-two game, however, not only are the incentives of
the motorist made manifest, but we can readily understand how a change
in the legal rules alters the incentives of the motorist and the pedestrian
at the same time.

To see this, consider the legal regime of negligence coupled with
contributory negligence. This is the regime that Anglo-American law
has embraced for a long time. Under this regime, the pedestrian can
recover only if the motorist is negligent and if the pedestrian is not. This
rule of law leads to the normal form game set out in figure 3:

<p style="text-align:center">Motorist</p>

		No Care	Due Care
	No Care	-100, 0	-100, -10
Pedestrian			
	Due Care	-10, -100	-20, -10

<p style="text-align:center">Payoffs: (Pedestrian,   Motorist)</p>

<p style="text-align:center">FIGURE 3: NEGLIGENCE WITH CONTRIBUTORY NEGLIGENCE</p>

Compare figure 3 with figure 2. The two figures are identical except
in the box in which the pedestrian exercises "due care" and the motorist
fails to do so. In this event, the motorist rather than the pedestrian bears
the cost of the accident. The pedestrian bears the cost of the accident
whenever the pedestrian fails to exercise care and in the case in which

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16. *See, e.g.*, LANDES & POSNER, *supra* note 9, at 62.

both players exercise care. The legal rule does not change the strategies available to the players or the sum of the payoffs in each box. All that changes is the allocation of the cost of the accident between the parties.

In this game, unlike the game in figure 2, the pedestrian has a dominant strategy. The pedestrian is always better off taking care. The motorist no longer has a dominant strategy. Whether the motorist is better off taking care turns on whether the pedestrian also takes care. If we accept the idea of iterated dominance, however, we can predict the strategy that the motorist will choose. The motorist will recognize that the pedestrian will play "due care" and then will decide to play "due care." Hence, under this legal regime, both the pedestrian and the motorist will take "due care."

A comparison between the two models focuses our attention on the way in which this legal rule works and reveals a counterintuitive insight about the role of law. The only difference between figure 2 and figure 3 is in the box representing the strategy combination in which the pedestrian exercises "due care" and the motorist does not. In figure 2, the payoffs were minus $110 and zero dollars for the pedestrian and the motorist respectively. In figure 3, they are minus ten dollars and minus $100. This strategy combination is not the solution to either game: In figure 2, neither player exercises care, while in figure 3 both players exercise care. Yet it is how the negligence/contributory negligence regime reallocates the harm when the pedestrian takes care and the motorist does not—an outcome that is not reached in either game—that completely alters the expected play of the game. Under either liability rule, we would never expect to observe the pedestrian exercising "due care" and the motorist exercising "no care," but it is precisely how the law treats the outcome that will not happen that determines whether the efficient (due care, due care) outcome occurs. *A legal rule brings about changes through the consequences it attaches to behavior that never happens either when the legal rule is in place or when it is not.*

This model also focuses on a central assumption underlying the Anglo-American rule. To believe that this rule works, we must believe both that the motorist acts rationally and that the motorist believes that the pedestrian acts rationally as well. The motorist will take care in order to avoid liability only if the motorist believes that the pedestrian is similarly motivated; that is, that the pedestrian will act to avoid bearing the cost of the accident and will therefore take care. If the motorist believed that the pedestrian would not take care, the motorist would not take care either. This liability rule turns crucially on the assumption that the motorist believes that the pedestrian will exercise "due care."

This explicit game-theoretic approach isolates two features of the law in a useful way. First, it makes clear the rationality assumptions required. We must assume not only that individuals behave rationally, but also that individuals expect others to behave rationally. Second, this way of looking at the problem reveals one of the important, but subtle ways in which a legal rule works. A change in a legal rule can alter the behavior of both parties even by changing outcomes that are never seen under either the new or the old regime.[17]

III. EXTENSIVE FORM GAMES AND BACKWARDS INDUCTION

Not all games or legal situations can be resolved using dominance arguments. For example, consider the problem of choosing on which side of the road to drive. In this country, we drive on the right-hand side, in England, on the left. Think of two players faced with that choice in the absence of a governmental setting:

	Player 2 Left	Player 2 Right
Player 1 Left	4, 3	0, 0
Player 1 Right	0, 0	3, 4

Payoffs: (Player 1, Player 2)

FIGURE 4: DRIVING COORDINATION GAME (NORMAL FORM)

Player 1 has a slight preference for driving on the left, player 2 for the right, but both care most about making the same decision. (For that reason, this game is often labeled a *coordination game*.) Neither player has a dominant strategy, nor is any strategy a dominated strategy. What then is the likely outcome? There is another important approach to solving games, though it will be of only some help here. Consider the following idea: If player 1 knew that player 2 were to play "left," player 1 would play "left" as well, and the flip side of that is true as well. The same is true of the combination (right, right): player 1 would play "right" in response to player 2's "right," and player 2 would play "right" in response to player 1's "right." (Left, right) and (right, left) lack this

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17. For an additional analysis of tort issues from the perspective of dominant and dominated strategies, see Daniel Orr, *The Superiority of Comparative Negligence: Another Vote*, 20 J. LEGAL STUD. 119 (1991), and Tai-Yeong Chung, Efficiency of Comparative Negligence: A Game Theoretic Analysis (Jan. 28, 1992) (unpublished manuscript, on file with *Loyola of Los Angeles Law Review*).

quality: If player 1 chose to play "left" but before committing learned that player 2 was going to play "right," player 1 would abandon "left" and instead play "right." (Left, left) and (right, right) have a stability that the other two outcomes lack. The game theory lingo for this is that both (left, left) and (right, right) are "Nash equilibria," Nash coming from the great game theorist John Nash. This game has two pure strategy Nash equilibria. (Pure strategy is more lingo for saying that neither player is playing in a probabilistic fashion.)

In some settings a game will have a unique Nash equilibrium, and it is perhaps understandable that such an equilibrium is considered the most natural outcome to the game. Unfortunately, as in figure 4, many games have multiple Nash equilibria and the games themselves offer no good means for the players to coordinate on those equilibria. As a consequence, if the game in figure 4 were played in an experimental setting, I would expect to see a sizable number of non-Nash (left, right) and (right, left) outcomes. The players would not be happy about this, as this is the worst outcome for them, but the problem with the game is that the players lack any good means for coordinating their choices. Sometimes player 1 would hope that the (left, left) Nash outcome was going to be played while player 2 would be hoping for the (right, right) Nash outcome, and that puts the players squarely on (left, right).

Subject to the previously introduced Churchill caveat, legal intervention might again be appropriate. To get at this and to introduce another form for representing games, suppose for example the government gave the first person the right to set the rules of the road. This game could be represented in the following way:

Player 1 moves left   Player 1 moves right

Player 2

Left   Right   Left   Right

(4, 3)   (0, 0)   (0, 0)   (3, 4)
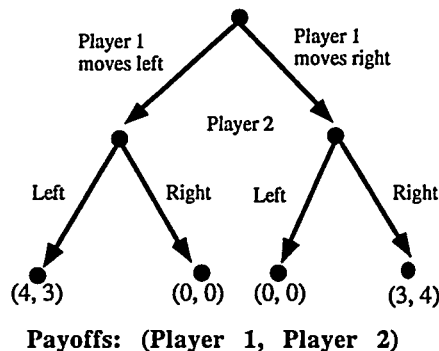
Payoffs: (Player 1, Player 2)

FIGURE 5: DRIVING SEQUENTIAL GAME (EXTENSIVE FORM)

This game represents the players' choices through something akin to a decision tree. This representation is known as the *extensive form* of a

game. Figure 5 differs from a decision tree in that it represents decisions by two players, but the basic idea is the same. Pursuant to governmental edict, player 1 chooses first, player 2 second, and each still chooses between "left" and "right." In this game, player 2 observes player 1's choice, which is the essential difference between this game and our prior game in figure 4.

This game can be solved using another solution technique, *backwards induction*. If player 1 moves "left," player 2 will choose between "left," with a payoff of three and "right" with a payoff of zero. Player 2 would clearly play "left." If player 1 moves "right," player 2 will choose between "left," with a payoff of zero and "right" with a payoff of four, and hence will choose "right." Player 1 thus faces moving "left," and receiving four and moving "right" and receiving three, and hence would move "left." Legislation changing the sequence of moves turns a simultaneous decision-making game into a sequential game and establishes a clear outcome. The indeterminacy of the simultaneous game is eliminated. Note that the government allocation of the right to move first has distributional consequences. In this game, player 1 receives four and player 2 gets three. If the right to move first were allocated to player 2, player 2 would get four and player 1 would receive three.

Setting standards, such as establishing the rules of the road, is a conventional use of governmental power. The games in figures 4 and 5 should make clear the possible benefits associated with these activities.

IV. EMBEDDED GAMES: CAVEAT LEGISLATOR

I started the analysis with the Prisoner's Dilemma as it is easily the best-known game and is most often invoked in defense of legal intervention. Such an analysis often does little more than suggest that a particular situation has the form of the dilemma and then to claim that intervention would be appropriate. This may be a serious mistake. Whether the Prisoner's Dilemma creates problems depends on the larger structure in which the game exists. Put differently, a small game, such as the Prisoner's Dilemma, may arise in a much larger game. The very existence of the Prisoner's Dilemma in the large game may have beneficial, rather than negative consequences. A simple example should make this clear. Consider the games set forth in figure 6:

	Player 2	
	Left	Right
Up	2, 2	3, 1.5
Down	1.5, 3	2.5, 2.5

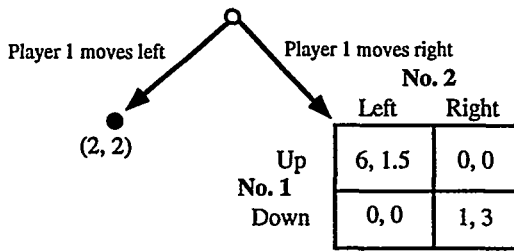|	Player 2	
	Left	Right
Up	6, 1.5	0, 0
Down	0, 0	1, 3

Payoffs: (Player 1, Player 2)

FIGURE 6: PRISONER'S DILEMMA (LEFT) AND
COORDINATION GAME (RIGHT)

Figure 6 illustrates a Prisoner's Dilemma and a coordination game. (I have changed the payoffs from the prior versions of these games, but that is irrelevant here.) In the first game in figure 6, player 1 will play "up," as that is his dominant strategy. (If player 2 were to play "left," player 1 gets a payoff of two from "up" and a payoff of one-and-a-half from "down"; if player 2 were to play "right," player 1 would get a payoff of three from "up" and of two-and-a-half from "down"; "up" is therefore a dominant strategy.) Player 1 and player 2 are in symmetric positions in the first game, so player 2 has a dominant strategy of "left." Both players have dominant strategies, resulting in the payoff of (2, 2), which is worse than (2.5, 2.5) from (right, right).

The second game in figure 6 is a coordination game, meaning here, as before, that the game has two pure strategy Nash equilibria. The strategy combination (up, left) is one equilibrium: If player 1 were to play "up," player 2 would want to play "left," as that results in a payoff of one-and-a-half rather than the payoff of zero obtained by playing "right." And if player 2 were to play "left," player 1 would prefer "up" and six to "down" and zero. Thus, (up, left) forms a Nash equilibrium. A similar analysis holds for (down, right). As before in figure 4, game theory offers us little basis for choosing between these two equilibria.

That is where the Prisoner's Dilemma comes in; it will take us two steps to get there. Start with the game set forth in figure 7:

Payoffs: (Player 1, Player 2)

FIGURE 7: EMBEDDED COORDINATION GAME (MIXED FORM)

I have embedded the coordination game from figure 6 into a larger game. In this game, player 1 makes an initial move in which player 1 has a chance to decide between taking a certain payoff of two or playing a coordination game. If the coordination game is played, player 2 knows that player 1 has elected to forego the certain payoff of two and has instead chosen to play the coordination game with player 2. This coordination game is identical to that in figure 6. In that game, player 1 and player 2 move simultaneously, and, most importantly, neither can observe the choice of the other.

Now consider how player 1 and player 2 should reason. Player 2 decides whether to play "left" or "right" only after observing that player 1 has moved "right." Player 2 does not know whether player 1 moved "up" or "down," but player 2 should not expect player 1 ever to move "down" after having moved "right." Moving "down" is dominated by any strategy in which player 1 moves "left." Player 1's maximum payoff of one in the game that follows after playing "right" followed by "down" is dominated by the payoff from playing "left." Hence, if player 1 moves "right," player 1 should follow that move by moving "up." Were player 1 to do otherwise, player 1 would have adopted a dominated strategy. Believing that others would not play dominated strategies, player 2 will play "left" in response to player 1's initial move of "right." Because player 2 believes player 1 will move "up" after moving "right," player 2 ensures a payoff of one-and-a-half rather than zero by moving "up." Player 1, recognizing that player 2 will move "left," will play the strategy of moving "right" and "up" and enjoy a payoff of six, rather than one in which player 1 moves "left" and enjoys a payoff of only two. Even

though this coordination game standing alone does not have a unique solution, it does have one when it is part of a larger game.[18]

Now take the next step. Replace the solitary payoff of (2, 2) with our Prisoner's Dilemma game from figure 6:

Player 1 moves left   Player 1 moves right

No. 2   No. 2
Left   Right   Left   Right

	Left	Right
Up No. 1	2, 2	3, 1.5
Down	1.5, 3	2.5, 2.5

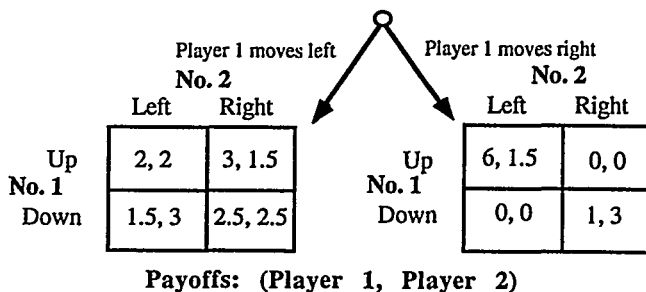|	Left	Right
Up No. 1	6, 1.5	0, 0
Down	0, 0	1, 3

Payoffs: (Player 1, Player 2)

FIGURE 8: EMBEDDED PRISONER'S DILEMMA AND COORDINATION
GAMES

In this game, player 1 moves "left" or "right" first, and this move is observed by player 2. If player 1 moves "left," the Prisoner's Dilemma game is played. If player 2 moves "right," the coordination game is played.

How should this game be solved? In the same way we solved the game in figure 7. In the Prisoner's Dilemma, each player has a dominant strategy and a payoff of (2, 2) should result. If player 1 were to play "left," he would obtain two. That payoff is better than any payoff that can result by playing "right" followed by "down." Hence, player 1 would follow "right" only with "up." Player 2 should understand this and play "left" following player 1's initial "right." This would result in a payoff of six to player 1. Player 1 should therefore play "right" followed by "up" and player 2 should play "left." This results in payoffs of six and one-and-a-half, for a total of seven-and-a-half, the maximum available on these particular (and cooked) numbers.

Step back and note what has happened. We started with two games in figure 6, the Prisoner's Dilemma and a coordination game. Taking either of these as freestanding games would suggest that legal intervention might be appropriate. The Prisoner's Dilemma plays out inefficiently, and the existence of multiple equilibria in the coordination game means we can have little confidence of an efficient outcome there. Yet, bring these two games together in a single larger game, and private

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18. This is an example of *forward induction*. For an introduction, see DREW FUDENBERG & JEAN TIROLE, GAME THEORY, § 11.3 (1991).

decision making leads to an efficient outcome. The very existence of the Prisoner's Dilemma makes it possible to coordinate on a particular Nash equilibrium in the coordination game.

The punch line here is that game structure matters, and often matters a lot. Identification of the game itself is of great importance. Misidentification usually occurs when the small, freestanding game is viewed as *the* game. A modeler who focused on the interaction captured in the Prisoner's Dilemma in figure 8 rather than the entire game would be misled. It is a mistake to suggest that a Prisoner's Dilemma may arise in a particular context and to use that to justify legal intervention. The larger game structure must be understood, as these rather stylized games suggest. The counterintuitive (at least to me) suggestion of figure 8 is that the existence of a scenario in which a Prisoner's Dilemma game might arise actually *helps* the players to achieve the best outcome.

All of this should introduce a level of caution into willy-nilly invocations of the Prisoner's Dilemma as a basis for legislation. More generally, it is critical to understand the context in which a particular game occurs and the extent to which it is embedded in a larger game.[19] Understanding that may make it clear that the very form of the game is up for grabs. For example, the dominant theoretical justification for bankruptcy is that creditors of the failing firm face a collective action problem akin to that in the Prisoner's Dilemma.[20] (This is often called the common pool problem.) One solution is a government-created collective procedure, the modern bankruptcy proceeding. Nonetheless, to accept that the creditors of the firm must play the financial equivalent of the Prisoner's Dilemma is a mistake. Together with the debtor, the creditors have an interest in taking actions ahead of time to mitigate the possible harms of the dilemma. Security interests can be understood as one important way of completely avoiding the dilemma.[21] Again, the point here is that we must understand the context in which a game would otherwise take place. The game in figure 8 makes this point—I hope—in relatively stark fashion.

V. CONCLUSION

This Essay sketches out some of the basic ideas of game theory. There is a standard language for representing situations—giving rise to

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19. For a similar point in a political science context, see GEORGE TSEBELIS, NESTED GAMES: RATIONAL CHOICE IN COMPARATIVE POLITICS 7 (1990).

20. *See* THOMAS H. JACKSON, THE LOGIC AND LIMITS OF BANKRUPTCY LAW 10 (1986).

21. *See* Randal C. Picker, *Security Interests, Misbehavior, and Common Pools*, 59 U. CHI. L. REV. 645 (1992).

the normal form and extensive form games—and ways to discuss solutions—such as dominant strategy solutions, Nash equilibria, backwards induction, and forward induction. Of more importance to the intellectual arbitrager, I hope that I have suggested a number of ways in which these ideas help us generate counterintuitive insights about legal problems. The central lesson of the torts example is that a legal rule brings about changes through the consequences it attaches to behavior that never happens, either when the legal rule is in place or when it is not. I found that surprising. I found even more surprising the notion that having a Prisoner's Dilemma handy might actually help solve collective action problems, rather than create them, and that this should make us cautious in relying on the Prisoner's Dilemma to justify legal intervention. I would have found it difficult to reach either of these points without using game theory, though there very well may be other routes.

I return to arbitrage and sure profits. There is a darker side to arbitrage than the opening of the Essay suggests. The absolutely safe "buy at five, sell at ten" opportunity rarely exists. Indeed, arbitrage is sometimes described as "picking up dimes in front of a bulldozer," which captures rather graphically the possible risks of the practice. Intellectual arbitrage has its risks as well. Not every idea that succeeds in one field can cross over successfully to another. The trick of course is to know which is which, since, unlike investment managers who can put together a diversified portfolio of holdings, intellectual arbitragers are usually poorly diversified—this is "law and . . ." and not "law and . . . and . . . and . . ." for a reason—and can at best hope to master and carry over some subfield of a much larger discipline. (And at the same time stay absolutely current on legal developments in our chosen substantive fields of law—no one said interdisciplinary work came cheaply!) The only thing one can say with any confidence is that law and economics scholars have started to put their chips on the table in a bid to shape the next generation of law and economics, and that the size of the stacks on game theory is growing.

I hope we are right.