Deterrence and Aggregate Litigation

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Abstract: This paper examines the deterrence properties of aggregate litigation and class actions, with an emphasis on positive value claims. In the multiple victim scenario with positive value claims, in the absence of the class action device, the probability that an individual victim will bring suit falls toward zero with geometric decay as the number of victims increases. The reason is that the incentive to free ride increases with the number of victims. Deterrence does not collapse but is degraded. Undercompliance is observed, which worsens as the number of victims increases. Compliance is never socially optimal, and the shortfall from optimality increases with the number of victims. These results, which continue to hold even if victims anticipate being joined in a single forum, suggest a more nuanced and potentially more robust justification for the class action than has hitherto been provided. Implications for collusive settlements of class action litigation are discussed.

JEL Classifications: K40, K41, K42, K22, D74

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1. Introduction

Rights without remedies traditionally have been viewed as anomalies in the law. As a result, the class action, permitting one or several litigants to sue on behalf of a large group of victims, developed as a means of providing a remedy in multiple-victim settings where individual incentives to sue are inadequate.

Usefully, class action lawsuits have been put into two categories: those consisting of negative expected value claims, where the expected individual recovery would be less than the claimant's cost of litigation (for example, consumer claims), and those consisting of positive expected value claims (for example, securities claims). For negative expected value claims, aggregation within the class action device is necessary to create a suit with a positive expected value. This has been offered as the fundamental justification for class actions (Coffee 2015).[1] For positive expected value claims, the social desirability of the class action device is less clear because every claimant can profitably bring his own lawsuit.[2] To be sure, the literature has offered several theories that can be used to justify positive claim class actions on social welfare grounds.[3] Still, despite the importance of the topic as evidenced by the passage of two federal statues regulating class actions,[4] the law and economics literature has given relatively little attention to the deterrence properties (ex ante effects) of aggregate litigation and class actions.[5]

[1] Posner makes the same point in Eubank v. Pella Corp., 753 F.3d 718 (7th Cir. 2014) ("The device is especially important when each claim is too small to justify the expense of a separate suit, so that without a class action there would be no relief, however meritorious the claims.")

[2] Most discussions assume risk neutral agents who would choose to sue whenever the expected value of the claim is positive. If, instead, subjective preferences were taken into account, the welfare effects of both negative and positive value claim aggregation would be difficult to assess. Aggregation might benefit those who would prefer to sue but do not do so because of a lack of information on the existence of a potential claim, but might injure those who are fully informed but would prefer not to sue (Eisenberg and Miller, 2004, at 1529-30).

[3] See Spier (2002) and Bone (2003) on efficiency in reducing litigation costs and management of externalities in limited fund litigation. Rosenberg and Spier (2014) examine incentives to invest in litigation, and specifically the class action's ability to equalize investment incentives for plaintiffs and defendants. Che and Spier (2008) examine settlement pathologies in multiple plaintiff settings with a fixed cost of litigation shared among plaintiffs.

[4] I refer to The Class Action Fairness Act of 2005 and The Private Securities Litigation Reform Act of 1995.

[5] Among the relatively few exceptions are Bone (2003) and Ulen (2011). The formal economic analyses have tended to focus on ex post settlement incentives. Che and Spier (2008) examine the settlement process and discuss implications of their analysis for injurer incentive dilution. This paper's model, by contrast, focuses on ex ante incentive effects, and particularly the influence of litigation costs on deterrence (Shavell, 1982; Hylton, 1990).

This paper examines the deterrence properties of aggregate litigation and class actions, with an emphasis on the positive value claim setting. I find that in the multiple victim scenario with positive value claims, the probability of suit goes to zero (in the absence of the class action device) with geometric decay as the number of victims increases. This is due to strategic behavior, as the incentive to free ride (that is, wait for another litigant to first establish liability) increases with the number of victims. Deterrence does not collapse, as in the case of negative value claims, but is degraded.

Undercompliance results because free riding reduces aggregate liability below aggregate social harm. The difference can be made up only if the litigation cost burden on the defendant increases with the number of victims. But the litigation cost burden threatened by any particular victim shrinks to zero because of the decline in the individual probability of litigation.

Compliance with the law is always less than socially optimal, and the extent of the shortfall from social optimality increases with the number of victims. This is a fundamental problem – again attributable to strategic behavior – that can be solved most effectively through the class action device. In theory, fee shifting could also solve the underdeterrence problem, but in reality it is unlikely that any fee shifting scheme could completely remove the incentive to free ride among victims.

The free riding result holds even if the first-filing victims anticipate joining in a single action, thus reducing their litigation expenses substantially. The reason is that although joinder reduces litigation costs, it does not eliminate the incentive to free ride and the resultant undercompliance.

The core results of this paper suggest a more nuanced and potentially more robust justification for the class action.[6] In addition, the results have implications for the effectiveness of class action litigation. The problem of collusive "settlements",[7] where the class action attorney terminates the action in exchange for a side payment from the defendant, appears to be governed by the same dynamics as the private litigation incentive. Thus, even if the payoff to a monitor (to guard against collusion) were positive, the incentive to free ride implies that the probability of any individual plaintiff choosing to monitor decays to zero as the class size expands, and further the probability of monitoring by any class member falls as the cost of monitoring rises relative to the individual payout. I also examine the deterrence properties of statutory damages actions and class actions, common in the consumer protection field.

[6] To be sure, the literature examining settlement incentives offers important justifications for class actions (Spier, 2002, Che and Spier, 2008). The justifications implied in that literature follow from inefficiencies in the settlement process.

[7] Collusive settlements are not really settlements as traditionally understood, but terminations in exchange for a side payment from the defendant to the class action lawyer.

Statutory damages class actions can enhance welfare, but only if the statutory award is less than the sum of the harm and the plaintiff's cost of litigation. Lastly, I consider the model's implications for some issues in securities litigation, such as the phenomenon of opting out and the likely outcome from abolishing securities class actions.

Part 2 presents the basic model. Part 3 examines the effects of private litigation with multiple victims on incentives to comply with the law and on the social optimality of compliance. Part 3 illustrates the geometric decay of deterrence and also demonstrates that compliance is always socially inadequate in the multiple victim private litigation setting. Part 4 considers the implications of permissive joinder of victims. Part 5 discusses extensions and implications of the basic model.

2. Basic Model

There are $n > 1$ victims. The injurer imposes a loss on each of v, and each faces a litigation cost $c_p > 0$. The injurer/defendant bears litigation cost $c_d > 0$. The litigation costs are incurred only if the parties litigate to judgment. The injurer can take care, incurring a cost of $x > 0$. If the injurer does not take care, the probability of injury to each victim is $p > 0$. If the injurer does take care, the probability of injury to each victim is q, where $p > q$.

The injurer is assumed to have sufficient assets to compensate all of the victims. Liability is strict, and the injury to each victim is assumed to arise from a single transaction.[8] Thus, proof of liability by one victim establishes liability for any other victim.[9] Put in legal terms, there is one common issue of fact and law (specifically, did the injurer comply with the law?) that the court will consider to determine liability to all victims who sue.

Victims have "negative value claims" if $v \leq c_p$ (assuming victims do not sue when indifferent) and positive value claims if $v > c_p$. Equivalently, letting $\lambda = c_p/v$, victim claims are negative if $\lambda \geq 1$, and positive if $\lambda < 1$. Adopting a parallel notation for defendants, merely for simplicity of expression, let $\theta = c_d/v$.

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[8] Strict liability is associated with many of the areas in which the availability of the class action has made litigation more likely: for example, securities litigation (Section 10b5 securities fraud lawsuits), consumer fraud (e.g., Truth in Lending Act, Fair Debt Collection Practices Act, etc.), environmental litigation (e.g., Comprehensive Environmental Response, Compensation, and Liability Act (also known as Superfund)).

[9] In legal terms, this model assumes *offensive estoppel (issue preclusion)*: having been found guilty of the violation in one lawsuit, the defendant is precluded from relitigating liability in a later lawsuit arising from the same transaction. On offensive issue preclusion, see Parklane Hosiery Co. v. Shore, 439 U.S. 322 (1979). Che and Yi (1993) examine an asymmetric information model of litigation with issue preclusion, finding that the first plaintiff can extort a large settlement.

2.1. Litigation

First, note that if claims have negative value ($\lambda \geq 1$), no victim will bring suit, and the injurer will not take care, which is the traditional justification for the class action device. For the remainder it will be assumed that victims have positive claims.

The timing of events leading to litigation is as follows. In the first period, the victim decides whether to accept a settlement or to litigate. If the victim chooses to settle the litigation comes to an end. If the victim rejects settlement, then he commits to litigation. In the second period, after having committed to litigation, the victim chooses either to "Sue" or to "Wait," where the former strategy involves suing immediately and the latter involves waiting to take advantage of legal precedent created by an earlier plaintiff. If a victim sues immediately his payoff is $v - c_p$. If a victim chooses to wait and some other victim sues immediately, the waiting victim receives v, because he avoids the cost of having to prove liability. If all victims wait, their payoffs are equal to zero, because evidence has grown stale and no prior litigant has been able to take advantage of the evidence to prove the defendant's violation. Transaction costs prevent the victims from coordinating in advance.[10]

Examining pure strategies, there are multiple equilibria in the second period - specifically, any outcome in which only one victim sues and the others wait. Expanding the analysis to (symmetric) mixed strategies,[11] the victim chooses the probability of suit, a, to equalize the payoff from suing immediately ($v - c_p$) and the payoff from waiting. Since waiting has a positive reward only if some other victim brings suit, the payoff from waiting is $[1-(1-a)^{n-1}]v$. Equating the two, the equilibrium probability of suit is $a^* = 1 - \lambda^{\frac{1}{n-1}}$.

Given a^*, will victims settle in the first period or commit to litigation? To secure a settlement, the injurer will have to offer each victim an amount that is no less than the value of the victim's litigation option $a^*(v - c_p) + (1- a^*)\,[1-(1- a^*)^{n-1}]v = v - c_p$. Thus, the injurer will offer $v - c_p$. However, each victim has a weakly dominant strategy to hold out for a payment that appropriates the settlement surplus, $v + c_d + nc_p$. Victims hold out in equilibrium, leading to litigation.

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[10] See Bone (2011), which also notes that the incentive to free ride will hinder any effort to communicate among victims to form the equivalent of a class lawsuit through voluntary joinder.

[11] Symmetry is easily justified given that the victims are essentially the same. Suppose all lawyers sued immediately. Some lawyers could then gain by waiting, and $1-a^*$ would be the percentage of "waiters" at which the expected profit advantage from waiting fully dissipates. That some lawyers choose to wait rather than sue immediately was noted by the Supreme Court in *Parklane Hosiery*.

Proposition 1: *For multiple positive claim victims, the equilibrium probability of suit being brought by an individual victim is* $a^* = 1 - \lambda^{\frac{1}{n-1}}$. *Thus, as the number of victims goes to infinity, each victim's probability of suing goes to zero.*

This is analogous to the "bystander effect," which explains why the probability of any particular bystander coming to the aid of a person in distress falls as the number of bystanders increases (Darley and Latane, 1968; Diekmann, 1985; Leshem and Tabbach, 2016). Here, the victim, when deciding whether to pursue a private lawsuit, focuses only on the payoff from suing immediately relative to that for waiting, which is dependent on the actions of other victims. For any given suit probability, the payoff from waiting increases as the pool of victims grows larger. In the limit, this incentive to free ride causes the individual probability of suit to fall toward zero. Although it might appear at first that deterrence should collapse as result of this process, the implications for deterrence are more complicated.

2.2. Effect of Change in Award or Cost

As one would expect, the equilibrium (individual) suit probability is decreasing in the plaintiff's cost of litigation:

$$\frac{\partial a^*}{\partial c_p} = \left(\frac{-1}{n-1}\right)\lambda^{\frac{1}{n-1}}\left(\frac{1}{c_p}\right) < 0$$

The larger is the plaintiff's litigation cost (provided it is less than the award), the smaller is the negative impact of its increase on the equilibrium suit probability.[12] This is intuitive given the existence of a limit where the plaintiff's cost is equal to the award, beyond which suits will not be brought. As the cost approaches the award, the sensitivity of the equilibrium suit probability to changes in the cost tapers off.

The equilibrium suit probability increases with the plaintiff's award:

$$\frac{\partial a^*}{\partial v} = \left(\frac{1}{n-1}\right)\lambda^{\frac{1}{n-1}}\left(\frac{1}{v}\right) > 0$$

This effect increases with the size of the award and decreases with the plaintiff's litigation cost. Not surprisingly in view of the free rider incentive, as the number of

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[12] This follows from

$$\frac{\partial^2 a^*}{\partial {c_p}^2} = \left(\frac{n-2}{(n-1)^2}\right)\lambda^{\frac{1}{n-1}}\left(\frac{1}{{c_p}^2}\right)$$

which is positive for $n > 2$, and zero for $n = 2$.

victims increases (and the likelihood of individual suit goes to zero), the sensitivity of the equilibrium suit probability to changes in either the award or the litigation cost goes to zero.

2.3 Expected Liability

The question immediately generated by the finding that the individual suit probability goes to zero as the number of victims increases is whether deterrence collapses in the same manner as the suit probability. If the injurer's expected liability decays as strongly as the individual suit probability then deterrence would inevitably collapse, and the justification for class actions in the positive value setting would be indistinguishable from that in the negative value setting. However, deterrence is a function of both the individual suit probability and the number of victims.

The expected liability of the injurer is[13]

$$E(L) = nv[1-(1-a^*)^n] + nc_d \cdot a^* \qquad (1)$$

The first terms reflects the discount on expected liability due to free riding and the second term reflects the total expected defense cost. This formulation, consistent with the basic setup, assumes that the defendant litigates against the first plaintiff (plaintiffs) and then compensates (without litigation) late-filing plaintiffs.

Substituting the equilibrium suit probability,

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[13] This answer can be arrived at intuitively, since the injurer avoids liability only in the outcome where everyone waits. The laborious route is as follows:

$$E(L) = \binom{n}{0} a^n \cdot (nv + nc_d) + \binom{n}{1} a^{n-1}(1-a)^1 \cdot (nv + (n-1)c_d) + \cdots + \binom{n}{n-1} a^1 (1-a)^{n-1} \cdot (nv + c_d) + (1-a)^n \cdot 0$$

$$= nv[1-(1-a)^n] + c_d\left[na^n + (n-1)\binom{n}{1} a^{n-1}(1-a) + (n-2)\binom{n}{2} a^{n-2}(1-a)^2 + \cdots + \binom{n}{n-1} a(1-a)^{n-1}\right]$$

$$= nv[1-(1-a)^n] + nc_d\left[a^n + \binom{n-1}{1} a^{n-1}(1-a) + \binom{n-1}{2} a^{n-2}(1-a)^2 + \cdots + \binom{n-1}{n-1} a(1-a)^{n-1}\right]$$

which is equal to the expression for expected liability in the text.

$$E(L) = nv\left[1 - \lambda^{\frac{n}{n-1}}\right] + nc_d\left[1 - \lambda^{\frac{1}{n-1}}\right].$$

As the number of victims increases, the first term behaves as $nv(1-\lambda)$, while the second term approaches a limit of $-c_d\ln(\lambda) > 0$. Thus, even though the probability of litigation by an individual victim goes to zero as the victim pool increases, expected liability remains positive – that is, deterrence does not collapse. This is because expected liability depends on both the number of victims and the probability that at least one will bring suit. As the number of victims expands, the probability that at least one will sue falls but eventually stabilizes at $1-\lambda > 0$.

Holding fixed the number of victims, expected liability shrinks to zero as the ratio of the plaintiff's cost to the award (λ) gets closer to one. In other words, deterrence does collapse as the plaintiff's cost rises to the level of the award, and this cost-induced collapse occurs more rapidly as the number of victims increases.[14]

It follows that expected liability increases as the award increases, both because of the direct effect and because of the indirect effect of increasing the probability of suit. Expected liability falls as the plaintiff's cost of litigation increases, because of the effect on the probability of suit.

One question generated by the structure of this model is why the defendant would litigate against filed claims. Although out of court settlements have been ruled out, why wouldn't the defendant simply pay off all filed claims for full value (e.g., by paying default judgments or making offers of judgment to the court)?

If the defendant chose not to defend at all, then the litigation cost barrier in the way of plaintiffs would disappear. The defendant can either pay off filed claims, incurring no defense costs, or litigate to judgment against the first positive value claims and pay off in full the remaining claims. The defendant will prefer the latter strategy to the former if the defendant's cost of litigation is less than the cost of deterring positive value claims.

Since litigation deters positive value claims by maintaining the plaintiff's litigation cost hurdle, a necessary and sufficient condition for litigation to be rational for the defendant is $nv > E(L)$.[15] Substituting the equilibrium suit probability, and θ, it follows that

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[14] This follows from

$$\frac{dE(L)}{d\lambda} = \left(\frac{-n}{n-1}\right)\left(\lambda^{\frac{1}{n-1}}\right)\lambda\left[nc_p + c_d\right] < 0,$$

which increases in absolute value with *n*.

[15] Suppose plaintiffs believe that the defendant will litigate, but the defendant has instead adopted a strategy to not defend when suit is filed. Under such conditions, the defendant would be even better off than paying off all claims. However, I rule out such an equilibrium because it requires naïve plaintiffs.

litigation is rational against the first positive value claimants if

$$\lambda^{\frac{n}{n-1}} > \theta\left[1 - \lambda^{\frac{1}{n-1}}\right] \qquad (2)$$

which, since $\lambda < 1$, is plausible for small n and sure to hold for large n. Thus, litigation is rational in the limit as the number of victims increases.

The defendant moves first by deciding whether to defend or simply pay off all filed claims, and the plaintiff moves second by choosing his litigation strategy a^*. Following the backward induction approach, I analyze outcomes in which the defendant decides whether to litigate based on the plaintiff's optimal strategy.

3. Compliance Incentives

Since deterrence does not collapse as a result of the free riding incentive, the remaining question is whether it is impaired. In this part I consider first the question of perfect compliance with the legal standard, and second the question of socially optimal compliance.

3.1 Perfect Compliance versus Socially Optimal Compliance

The equilibrium outcome is one of *perfect compliance* (or perfect deterrence, or first-best deterrence) if all injurers for whom

$$x < (p - q)nv \qquad (3)$$

choose to take care. This standard, which compares the cost of compliance to the social harm to victims directly resulting from noncompliance, is exemplified by the Hand Formula in tort law and other fault-based tests throughout the law.

Given that litigation is costly, *socially optimal compliance* (or deterrence) occurs when, given a^*,

$$x < (p - q)n[v + a^*(c_p + c_d)]$$

In words, compliance is socially optimal whenever the cost of compliance is less than the marginal social cost of failing to comply, taking into account the expected cost of litigation.

3.1.1 Perfect Compliance

An equilibrium of perfect compliance incentives is observed when the social harm from noncompliance is the same as the injurer's expected liability due to noncompliance:

$$(p-q)\cdot nv = (p-q)\{nv[1-(1-a^*)^n] + nc_d \cdot a^*\} \qquad (4)$$

Undercompliance results if marginal social harm (left hand side) is greater than marginal liability (right hand side). This implies:

Proposition 2: As long as litigation is a rational strategy for the defendant in the positive claim scenario, undercompliance will be observed. In addition, the degree of undercompliance increases with the number of victims. In the small n scenarios where litigation is not rational, perfect compliance will be observed. Overcompliance is never an equilibrium.

To see this, note that, simplifying (4) and substituting terms, undercompliance results if condition (2) holds, and (2) holds more strongly as the number of victims increases. Undercompliance is due to the free riding problem, whose effect might be avoided if the litigation cost burden on the defendant could make up for the dilution of liability. But given the defendant's optimal litigation strategy, and the vanishing likelihood of individual suit, the litigation cost burden cannot make up for the dilution due to free riding.

From the foregoing, the frontier along which private incentives are aligned with the legal standard, and compliance perfect, is

$$\frac{\lambda^{\frac{n}{n-1}}}{1-\lambda^{\frac{1}{n-1}}} = \theta$$

Proposition 2 indicates that the compliance level will be in the zone below this frontier (the undercompliance zone), which increases as the number of victims increases (perfect compliance holds both along and above the frontier).[16] The following simulations illustrate the rate of decay in compliance as the number of victims increases – showing that the decay is more severe from n = 2 to n =100 than from n = 100 to n = 1000.

[16] The zone above the frontier in Figure 1 would represent overcompliance equilibria if the injurer did not have the option of simply defaulting against the first wave of plaintiffs. The central results of this model would be the same.

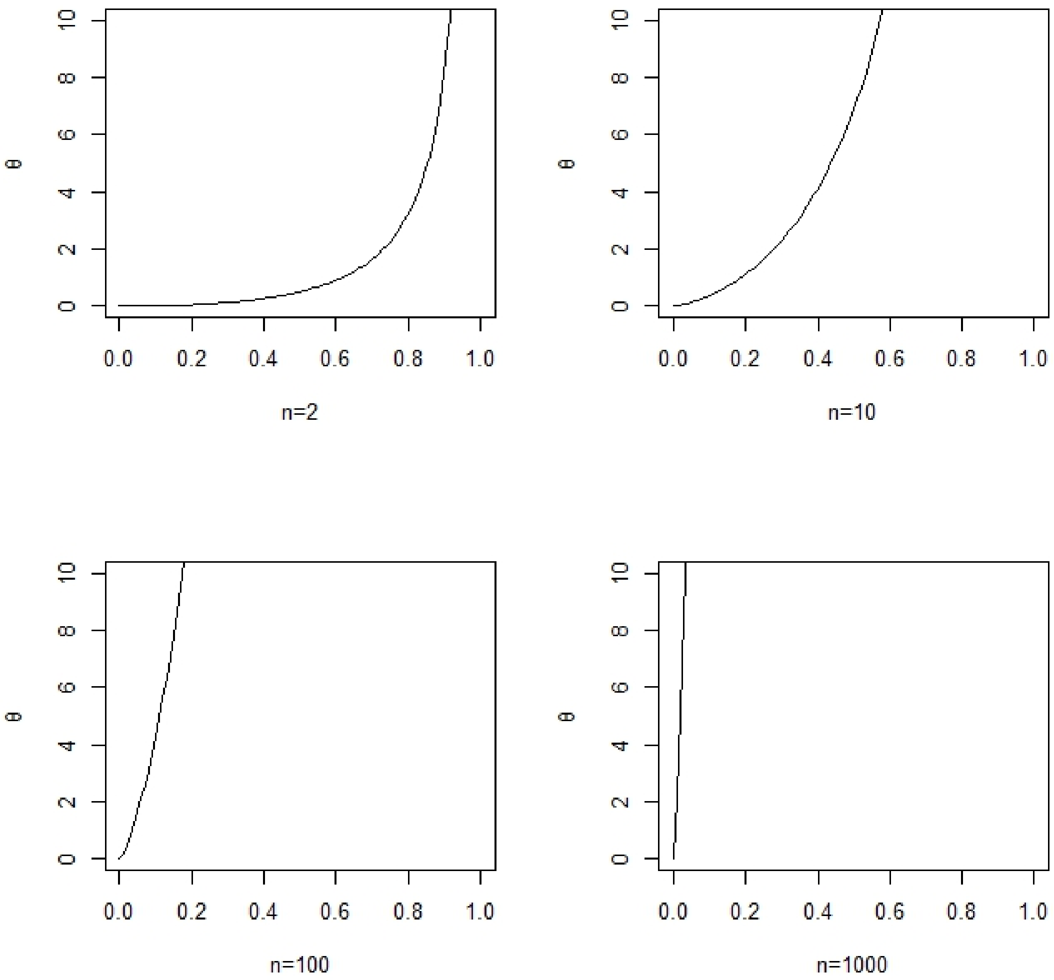

Figure 1: Compliance Effects of Litigation as the Number of Victims Increases

Notes: Horizontal axis: $0 < \lambda < 1$; vertical axis: $0 < \theta < 10$. Area below curve represents undercompliance zone. Area above and including curve represents perfect compliance zone.

3.1.2 Socially Optimal Compliance

For compliance to be socially optimal, the marginal social cost from noncompliance

$$(p-q)\cdot n[v+a^*(c_p+c_d)] \qquad (5)$$

must equal the marginal liability from noncompliance

$$(p-q)\{nv[1-(1-a^*)^n]+nc_d\cdot a^*\}. \qquad (6)$$

However, since the former is greater than the latter this result cannot hold. The following statement, a complement to the foregoing, establishes a basic result on aggregate litigation.

Proposition 3: *In the multiple victim private litigation scenario, the marginal social cost of noncompliance exceeds marginal liability. Thus, compliance is always less than socially optimal. Moreover, the degree to which compliance falls short of the socially optimal level increases with the number of victims.*

In the positive claim scenario under examination, the reason for this result is that the injurer does not expect to pay for all of the harms, given the strategic incentive to wait on the part of victims, and also externalizes litigation costs to plaintiffs.[17] This is similar to the result that strict liability underdeters relative to the social optimum when litigation is costly (Hylton, 1990). However, the strict liability underdeterrence result is due to the fact that litigation costs erect a barrier to some plaintiffs by creating negative value claims. Here, litigation costs do not erect a barrier to any claimant, because each is assumed to have a positive claim. It is the strategic interactions among plaintiffs, coupled with the externalization of litigation costs to them, that generate social underdeterrence. The distortion caused by strategic ambivalence among plaintiffs worsens as the number of victims increases.

The externalization of litigation costs potentially could be solved by shifting the plaintiff's costs entirely to the defendant. If such a shift were possible, then there would be no gain to a victim in playing the "wait" strategy. All victims would sue, and the marginal social harm from noncompliance would be equal to marginal liability.[18]

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[17] Proposition 3 is obviously true in the negative-value claim scenario, so there is no need to limit its scope to the positive-claim scenario.

[18] There is a separate issue as to whether suit should be barred in order to enhance social welfare. If expected litigation costs exceed the marginal deterrence benefit, then it may be optimal to bar litigation

Calculating the welfare loss from socially suboptimal compliance would require information on the distribution of the compliance cost *x*. Let the distribution be *G*(*x*) with corresponding density g; let $\underline{x}$ be the cutoff value equal to marginal liability, (5); and let $\overline{x}$ be the cutoff value equal to marginal social cost of noncompliance, (4). The welfare loss due to suboptimal compliance is

$$\int_{\underline{x}}^{\overline{x}} [(p-q)n[v+a^*(c_p+c_d)] - x]g(x)dx$$

Since the welfare loss increases with the wedge between marginal social cost and marginal liability, which is equal to $(p\text{-}q)nc_p$, the loss due to strategic ambivalence can be attributed generally to three factors: the productivity of care, the size of the victim pool, and the plaintiff's cost of litigation.

3.2 Example: Two Victims

For two victims, *A* and *B*, the payoffs can be shown in a familiar form:

		B's Choice	
		Sue	Wait
A's Choice	Sue	$v-c_p, v-c_p$	$v-c_p, v$
	Wait	$v, v-c_p$	0,0

The pure strategy equilibria are in the upper right and lower left corners. For the mixed strategy, if *A* sues his payoff is $a(v-c_p)+(1-a)(v-c_p)$, and if he waits his payoff is av; thus $a^* = 1-\frac{c_p}{v} = 1-\lambda$. Perfect compliance requires $(p-q)2v = (p-q)[2v(1-\lambda^2) + 2c_d(1-\lambda)]$, or $\theta = \frac{\lambda^2}{1-\lambda}$, which is the curve in the upper left panel of Figure 1.

4. Joinder of Plaintiffs

Under Federal Rules of Civil Procedure 20, plaintiffs may join in one action if "(A) they assert any right to relief jointly, severally, or in the alternative with respect to or arising out of the same transaction, occurrence, or series of transactions or occurrences; and (B) any question of law or fact common to all plaintiffs will arise in the action."

(Shavell, 1982).

Although permissive joinder advantages plaintiffs after they have filed suit by reducing their joint litigation expenses,[19] it would also reduce the defendant's expenses. Indeed, ex post – that is, after suit has been filed – joinder is always preferable from the perspective of the defendant, though it can be exercised only by the plaintiff. However, ex ante, joinder may not be desirable from the defendant's perspective because it encourages the filing of lawsuits. When the number of victims is large, however, the joinder and non-joinder policies have similar implications for the probability that an individual victim will bring suit.

4.1 Probability of Suit with Joinder

Proposition 4: *Even with the prospect of joinder, the individual probability of suit ($\hat{a}$) approaches zero as the number of victims increases*.

Thus, the free rider incentive remains, implying that the probability of suit declines as the number of victims increases, even when joinder of plaintiffs will occur. The reason is that although joinder reduces the victims' litigation costs dramatically, it does not eliminate the incentive among victims to strategically wait to allow another victim to first establish precedent. Even with permissive joinder of plaintiffs, the plaintiff who waits to file after liability has been established by the first litigant (or litigants) gains. As long as there is a gain to playing the "wait" strategy, deterrence is potentially compromised in the scenario of multiple victims with positive value claims.

Of course, the fact that the probability of suit falls to zero under the joinder policy does not imply that deterrence collapses. To consider the deterrence implications, I compare expected liability under the joinder and nonjoinder policies.

4.2 Expected Liability with Joinder

Comparing expected liability with joinder of plaintiffs to the expectation from the setting where there is no joinder,[20]

$$E(L_j) = (1-(1-\hat{a})^n)(nv + c_d)$$

$$E(L_{nj}) = n[v(1-(1-a^*)^n) + a^* c_d]$$

[19] Given the ex post advantage to plaintiffs, one could interpret the previous analysis of incentives under nonjoinder as implicitly assuming that transaction costs prevent the plaintiffs from opting for joinder.

[20] The derivation of $E(L_j)$ starts with the observation that $E(L_j) = \binom{n}{0}a^n \cdot (nv + c_d) + \binom{n}{1}a^{n-1}(1-a)^1 \cdot (nv + c_d) + \cdots + \binom{n}{n-1}a^1(1-a)^{n-1} \cdot (nv + c_d)$.

where $\hat{a}$ is the equilibrium probability of suit given that plaintiffs join and a^* is the equilibrium probability of suit under the assumption that plaintiffs do not join. Looking at the two expressions, it is unclear whether, for any given number of victims, expected liability is reduced ex ante by joinder of plaintiffs.

Just as in the non-joinder scenario considered previously, expected liability does not collapse in the joinder scenario as the number of victims increases, even though the probability of individual suit approaches zero. Substituting for the equilibrium suit probability in the non-joinder scenario, non-joinder of plaintiffs advantages defendants ex ante ($E(L_j) > E(L_{nj})$) if

$$(1-(1-\hat{a})^n)(nv+c_d) > nv\left[1-\lambda^{\frac{n}{n-1}}\right] + nc_d\left[1-\lambda^{\frac{1}{n-1}}\right],$$

and rearranging,

$$\frac{\theta}{n+\theta} + \frac{\lambda^{\frac{n}{n-1}} - \theta\left[1-\lambda^{\frac{1}{n-1}}\right]}{1+\frac{\theta}{n}} > (1-\hat{a})^n$$

Whether this holds for a given value of n, or as n goes to infinity,[21] is unclear. Thus, it is not clear, as a general matter, whether joinder of plaintiffs advantages defendants for any given number of victims or in the limit as the victim pool expands.

In the next part I offer an illustration, with two victims, of the conflict between the ex ante and ex post joinder preferences of injurers. The example also shows that the comparison between expected liability under joinder and nonjoinder is generally ambiguous, depending on the ratio of the plaintiff's cost to the award and the ratio of the defendant's cost to the award. In settings where joinder reduces expected liability, it may be harmful to plaintiffs, who control the joinder decision, because of its effect on incentives for compliance.

4.3 Example: Joinder with Two Victims

For two plaintiffs, expected liability under the joinder and non-joinder policies are:

$$E(L_j) = \hat{a}(2-\hat{a})(2v+c_d), \qquad \hat{a} = \frac{1-\lambda}{1-\frac{1}{2}\lambda}$$

[21] See appendix, Proposition 4.

$$E\left(L_{nj}\right) = 2a^*(2-a^*)v + 2a^*c_d, \qquad a^* = 1-\lambda$$

Joinder of plaintiffs, though optimal ex post for the defendant, is optimal ex ante for the defendant only if it reduces expected liability. The frontier consisting of (λ, θ) values for which the defendant is indifferent ex ante regarding joinder and non-joinder is shown as the boundary of the shaded area in Figure 2. In the shaded area nonjoinder is optimal ex ante for the defendant.[22] In the white region, joinder is optimal ex post for plaintiffs (which is always true) and optimal ex ante for defendants.

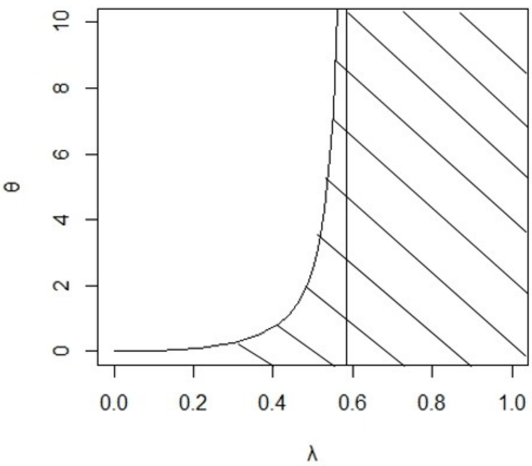

Figure 2: Ex ante versus ex post joinder incentives

4.3 Compliance under Joinder

Here I consider the questions of perfect compliance and socially optimal compliance under the joinder policy. Recall that compliance is less than perfect in the nonjoinder setting, as long as litigation is a rational strategy for the defendant, and undercompliance worsens as the victim pool increases.

In the joinder setting, victims are more likely to bring suit, which could improve compliance. Compliance is less than perfect under joinder if

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[22] $E(L_j) > E(L_{nj})$ in the regions:

$$0 < \lambda < 2-\sqrt{2} \ \ and\ \theta < -\frac{(3-\lambda)\cdot\lambda^2}{\lambda^2-4\lambda+2}$$

$$2-\sqrt{2} < \lambda < 1 \ \ and\ \theta > -\frac{(3-\lambda)\cdot\lambda^2}{\lambda^2-4\lambda+2}$$

Given that the boundary of the second region is to the right of λ = 1 for positive ϑ, Figure 2 provides a sufficient picture of the relevant region.

$$(p-q)\cdot nv > (p-q)(1-(1-\hat{a})^n)(nv+c_d)$$

A result similar to Proposition 2 holds: as long as litigation is a rational strategy for the defendant, compliance will be less than perfect. Rewriting this inequality:

$$(1-\hat{a})^n > \frac{\theta}{n+\theta}.$$

which holds for any given number of victims as long as litigation is rational for the defendant.

Consider what happens as the victim pool expands under joinder. Since the left hand side of the inequality above does not go to zero,[23] while the right hand side does, undercompliance results in the limit (again, as in Proposition 2). Although joinder can shrink the plaintiff's litigation cost to nearly zero, it does so for only a limited set of scenarios. The free rider incentive overwhelms the plaintiff cost-reduction effect.

Now consider the question of socially optimal compliance. Since compliance is less than perfect as long as litigation is rational, compliance will also be less than socially optimal, and in the limit the shortfall from social optimality remains.

Proposition 5: *Under joinder of plaintiffs, deterrence falls short of social optimality, and the shortfall worsens with the number of victims*.

The eventual underdeterrence outcome, as the victim pool increases, is due to free riding and the externalization of litigation costs to plaintiffs. Even though joinder increases the likelihood of suit, and therefore the expected litigation cost borne by the defendant, this is eventually insufficient to offset distortions away from optimality that result from free riding and the externalization of costs.

5. Extensions

5.1 Limited Fund Litigation

In the basic model in 2.1 it was assumed that the defendant had sufficient funds to compensate all victims. In "limited fund" cases, by contrast, there are multiple plaintiffs against a defendant with a fund insufficient to compensate all of them (Spier, 2002; Miceli and Segerson, 2005). The standard proposition is that plaintiffs race to the courthouse, resulting in unequal levels of compensation (e.g., Bone).[24]

[23] See appendix, Proposition 4.

[24] Spier (2002), in a careful examination of limited fund litigation, focuses on settlement incentives and finds that externalities among plaintiffs can result in socially inefficient litigation. For two plaintiffs, a

In this model, if there are two or more victims and only enough to compensate one, all sue immediately, which is the standard race. If there are n victims with only enough to compensate $m < n$, and if $k < m$ sue immediately, then waiting would be advantageous if $v\text{-}c_p < (m\text{-}k)v/(n\text{-}k)$. Still, as the number of victims increases, the residual goes to zero, implying that suing immediately would be privately optimal. These observations suggest that the incentive to free ride could exist even in the limited fund setting,[25] especially if the fund size is positively correlated with the number of victims. Products liability claims with numerous victims may exhibit this trait because the fund available for compensation is likely to be correlated with the number of victims who purchase the defective product.[26]

5.2 Class Actions and Social Optimality

The class action emerges naturally as a potential solution to the shortfall in deterrence discussed in previous parts of this paper. The class action solves the free riding problem by binding all of the victims into one litigation unit.[27]

The most plausible alternative to the class action is litigation cost shifting. If all of the litigation costs borne by victims can be shifted to the injurer, then no victim will have an incentive to free ride on the litigation of other victims. However, it would be impossible to shift all of the costs borne by the plaintiff to the defendant. As long as plaintiffs bear some special costs in litigating early, the strategic incentive to wait will remain.

Another alternative to the class action would a memoryless court system in which late-filing plaintiffs would be compelled to relitigate issues even against defendants who would rather settle. This would eliminate the free rider incentive, but it would be infeasible.

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race to the collect defendant's assets in settlement occurs only when the correlation between their claims is low. When the correlation is high, settlement is unlikely in the Spier model.

[25] In Miceli and Segerson (2005), examining suits for exposure, waiting can occur even in the limited fund scenario, where the first wave of exposure suits does not threaten to wipe out the defendant's assets.

[26] Breast implant litigation (Butler v. Mentor Corp. (In re Silicone Gel Breast Implant Prods. Liab. Litig.), MDL-926) and bone screw litigation (Fanning v. AcroMed Corporation , MDL–1014) serve as illustrations. These cases can be compared to that of bank deposit customers whose withdrawals do not necessarily threaten the bank's solvency even though the bank's funds are limited.

[27] In theory, permissive joinder might mitigate the free rider problem if courts denied offensive estoppel to late-filing plaintiffs who played the "wait" strategy, as suggested in *Parklane Hosiery*, 439 U.S. at 330. However, this would not eliminate free rider incentive. If the defendant knows the outcome of later litigation (i.e., that he will lose) he will settle the follow-on suits, which would induce free riding.

Consider the welfare potential of the class action. Although I have assumed all victims have positive claims, I relax this assumption here. Suppose the loss for each victim is the same and governed by the probability density $h(v)$. Since plaintiffs bring suit only when $v > c_p$, the marginal social harm from failing to comply is (assuming the class action is not available)

$$(p-q)\cdot n\{E(v)+a^*(c_p+c_d)\big[1-H\big(c_p\big)\big]\}$$

and marginal liability is

$$(p-q)\{nE(v|v>c_p)[1-(1-a^*)^n]+nc_d\cdot a^*\}[1-H(c_p)].$$

Clearly, marginal social harm remains larger than marginal liability, as in the previous analysis that assumed positive value claims. Availability of the class action alters marginal liability to:

$$(p-q)\{nE(v|v>\frac{c_p}{n})+c_d\}[1-H\left(\frac{c_p}{n}\right)]$$

and alters marginal social harm to:

$$(p-q)\left\{nE(v)+(c_d+c_p)\cdot[1-H\left(\frac{c_p}{n}\right)]\right\}$$

While, under the class action device, marginal liability is still smaller than marginal social harm for any given number of victims, the ratio of the two expressions approaches one as the victim pool size grows. It should be clear that the positive claims scenario is a special case and conforms. This suggests that as a practical matter, the class action is the only feasible solution to the welfare loss due to plaintiff incentive dilution.[28]

5.2 The Monitoring Problem

An important flaw in the class action device is that a lawyer managing such a suit may have an incentive to take a side payment from the defendant to "settle" (i.e., terminate) the case for a small or trivial payout to the class (Koniak 1995, Macey and

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[28] Awarding supercompensatory (punitive) damages to the first group of litigants could be another way to blunt the free riding incentive. If the punitive component is at least as large as the cost of litigation, no victims would gain by waiting. However, since punitive awards are given only in special cases of malicious or reckless conduct, this approach to correcting incentives would fail to blunt free riding in the general case.

Miller 1991).[29] This problem is especially likely for negative-claim classes. For example, suppose the plaintiff's cost of litigation is $11 and each of 100 victims has suffered a loss of $10. No victim would bring a suit on his own. The total class claim is $1000. Since the issues of fact and law are common within the class, the total class litigation cost is only $11. The lawyer, however, might choose to "settle" the case for a side payment of $200, and an award to the class of only $20.

Indeed, the defendant and the plaintiff's lawyer can always maximize their joint utility by arranging a side payment to terminate the case – that is, a collusive settlement. Thus, if no one monitors the class lawyer, the lawyer's optimal strategy is to take a side payment from the defendant. More generally the probability of a side payment occurring is likely to be the complement of the probability of monitoring: *P*(*side payment*) = 1 – *P*(*monitoring*).

To prevent a collusive settlement, some member of the class must therefore monitor the lawyer. But any such monitor would incur costs to oversee the lawyer while receiving the same benefits as other class members. Class members would therefore choose to free ride on the monitor.

The structure of the class action monitoring game is the same as that of the positive value class action game analyzed in Part 2. Consider, for example, a class consisting of 2 victims, with a monitoring cost of c_m.

		B's Choice	
		Monitor	Don't Monitor
A's Choice	Monitor	$v-\frac{c_p}{2}-\frac{c_m}{2}, v-\frac{c_p}{2}-\frac{c_m}{2}$	$v-\frac{c_p}{2}-c_m, v-\frac{c_p}{2}$
	Don't Monitor	$v-\frac{c_p}{2}, v-\frac{c_p}{2}-c_m$	0,0

This structure is the same as that of Proposition 4. For the *n* plaintiff case let

$$\sigma = \frac{c_m}{v-\frac{c_p}{n}}$$

which is the ratio of the cost of monitoring to the payoff to a non-monitoring class member.

Using the same argument as Proposition 4, the equilibrium monitoring probability

[29] In addition, a judge who must approve the settlement of a certified class may not have a strong incentive to reject a collusive settlement, given that any settlement reduces the court's workload (Helland and Klick, 2007).

within the litigation class, $\tilde{a}$, satisfies

$$\sigma[1-(1-\tilde{a})^n] = \tilde{a}[(1-\tilde{a})^{n-1}]n$$

As the number of plaintiffs within the litigation class increases, the equilibrium probability of a class member choosing to monitor the class attorney falls to zero.[30] However, the equilibrium probability that monitoring occurs is the probability that at least one member of the class chooses to monitor. This does not fall to zero, but converges to a value less than one.

Importantly, the probability of monitoring within the class decreases as the ratio of the cost of monitoring to the individual payoff from the class action increases (i.e., as σ increases). Letting $q = (1 - \tilde{a})^n$, the equilibrium monitoring probability condition can be expressed as:

$$\sigma(1-q)(1-q^{\frac{1}{n}}) = nq^{\frac{n+1}{n}}$$

Since $dq/d\sigma > 0$, the probability that at least one plaintiff within the class monitors, $1-q$, falls as σ increases.

If the claims are all negative value claims, the collapse of the class action (due to collusive settlement) that results because of the absence of monitoring would leave the plaintiffs with no other recourse. Their individual claims are worthless. If the claims are all positive claims, the collapse of the class action does not deprive the victims of the alternative of pursuing their claims individually. But this returns us to Proposition 1: as the number of victims increases, the incentive to pursue individual positive-value claims falls to zero. A more general proposition emerges: as the number of victims expands, the probability of individual actions falls to zero, degrading deterrence, and the probability of an effective class action weakens, also degrading deterrence.[31]

Monitoring can be restored if the monitor receives an additional payment out of the class award to compensate him for the costs of monitoring.[32] However, if it is the class action lawyer who permits the monitor to receive an award, then incentives for

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[30] This follows from applying the argument in Proposition 4.

[31] The dilution of deterrence described here does not imply that class action lawsuits will not be observed. Such lawsuits will continue, but with many ending in collusive settlements. Because the per-victim payoff is lower for negative-claims classes than for positive-claims classes, monitoring is less likely to occur for negative-claims classes. Unmonitored class actions are likely to serve a transfer rather than deterrence function.

[32] On the general efficiency of rewards as a solution to “volunteer’s dilemma” problems, see Leshem and Tabbach (2016).

monitoring are likely to remain poor. The class action lawyer has no incentive to fund an independent monitor. The lawyer would prefer to appoint a monitor who will give him maximal freedom to take a side payment if he deems such an action desirable.[33]

5.3 Statutory Damages and Aggregate Litigation

Another potential flaw in the class action device is observed in the setting where the award exceeds the harm. For example, in some cases victims who have suffered no harm, or very little harm, can obtain statutory damages and pursue class action litigation (Johnston, 2016). Statutory damages provisions are often included in consumer protection statutes.

The deterrence implications of statutory damages litigation can be examined within the basic model set out previously. Consider the scenario of individual lawsuits. Let D be the statutory damages award for each victim, $\tilde{\lambda} = \frac{c_p}{D} < 1$, and let $\pi = \frac{v}{D}$ be the ratio of the per-victim harm to the award. The free rider incentive remains in this scenario. However, the following deterrence result holds.

Proposition 6: *Compliance is socially optimal if and only if* $\tilde{\lambda} + \pi = 1$, *excessive if* $\tilde{\lambda} + \pi < 1$, *and inadequate if* $\tilde{\lambda} + \pi > 1$.

Statutory damages that precisely compensate for harm is the special case where $\pi = 1$, and compliance is socially inadequate as shown previously. Undercompensation of harm ($\pi > 1$) clearly results in inadequate compliance too. Since the no-harm case has $\pi = 0$, it follows that incentives to comply are socially excessive when there is no

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[33] Macey and Miller (1991) propose an auction of the class action right, with the lowest bidder prevailing as appointed counsel, to solve the agency cost problem described here. While such an auction has an appealing simplicity, it would still involve some problems, as noted in Bebchuk (2002). The winning bidder may have erroneously underbid (winner's curse), or may be ill-prepared or inadequately motivated to secure a large judgment. Moreover, the initial discovery and framing of a class action may require considerable effort on the part of an attorney. If the right is then auctioned off, after an attorney has developed the claim, it is unclear how the originating attorney will be compensated for his effort, and whether such compensation would be sufficient to encourage future development of claims. The Private Securities Litigation Reform Act of 1995 changed the law in securities litigation to require federal judges to appoint lead plaintiffs – on the theory that a judge-appointed lead plaintiff would be more effective as a monitor than one chosen exclusively by the attorney (Choi, Fisch, Pritchard 2005). However, even a court-appointed monitor would be afflicted by the free riding incentive and therefore shirk. The empirical evidence indicates that among post-PSLRA lead plaintiffs, only public pension funds appear to achieve above average results (Choi, Fisch, Pritchard, 2005). This raises the question whether such funds are able to secure a greater private benefit from class action participation than other investors (Webber, 2010).

harm, the opposite of the underdeterrence result established under the assumption that the award equals harm. The class action device only worsens excessive compliance in the no-harm scenario.

The intuition here is that when $\tilde{\lambda} + \pi = 1$, the real harm suffered by a prospective litigant is equal to the damages award ($v + c_p = D$), so that the award effectively removes the litigation cost hurdle that induces free riding. Generally, the class action can enhance welfare in the case where compliance is socially inadequate, $\tilde{\lambda} + \pi > 1$. Thus, even when the statutory award exceeds harm, the class action may still be socially desirable if the excess amount is less than the plaintiff's litigation cost.

5.4 Application to Securities Litigation

Securities litigation is a straightforward application for this model because positive value securities claims (e.g., fraud) available to multiple plaintiffs are not unusual. Moreover, free riding has been recognized as potentially serious in securities litigation. Webber (2015) describes incentives of institutional investors to assume lead plaintiff status in securities class actions:

> Fidelity, Vanguard, and TIAA-CREF are some of the largest institutional investors in the world, and undoubtedly have enough exposure to obtain lead-plaintiff appointments if they pursue them. But they don't. First, such funds are concerned about the cost of freeriding competitors, who are also likely to be class members….Hedge funds also avoid the lead-plaintiff role due to freeriding concerns. In addition, hedge funds tend to be secretive about their trading strategies and, thus, may be reluctant to subject themselves to the type of discovery that lead plaintiffs typically endure.

In view of the free riding incentive in securities litigation, this paper's results apply directly: the individual investor suit probability decays geometrically as the number of investors increases. In instances of fraud that actually harms investors, if the class action device were not available undercompliance and suboptimal compliance would result, and worsen with the size of the claimant pool.[34] The class action is potentially socially desirable because of these pathologies. On the other hand, similar dynamics apply to the individual incentive to monitor the class attorney, weakening the deterrence potential of the class action.

5.4.1 Opting Out

[34] Obviously, these implications are inconsistent with complaints of overcompliance resulting from class actions. As part 5.3 shows, overcompliance can be generated in this model, but it would require changing the basic assumptions – e.g., to allow for error by courts in applying the legal standard, or the filing of claims in the absence of real harm.

Observers of class action litigation have noted that opting out of securities class actions by positive claim victims has occurred more frequently, leaving the class consisting of negative claims (Coffee, 2015).[35] The positive claims are large institutional shareholders, with multimillion dollar anticipated awards. The decision to opt out typically occurs *after* a tentative settlement of the class action has been reached. The negative claim class left behind by opt-out litigants is vulnerable to the monitoring problem: no victim has an incentive to serve as a genuine monitor, so the lawyer is likely to enter into a collusive settlement.

In light of this model, opting out is both a type of symbiosis and a version of free riding by positive claims on the negative claim class. The entire combined class moves first, securing the outlines of a settlement through the participation (monitoring) of positive claimants, who then peel off to demand better terms. Their ability to demand better terms is facilitated by the negative claimants' credible threat to bring a class action suit. If the class action device were barred, the negative claims would never be credible, and the positive claimants would then each face the strategic game of choosing whether to sue immediately or wait for some other positive claimant to sue first – that is, the scenario of Proposition 1.

5.4.2 Additional Implications

If the class action were abolished in the securities area, the positive claimants, institutional investors, would still be compelled to sue according to Webber because of their fiduciary duty to clients. But each firm might be able to defend a decision not to sue immediately on the ground that waiting could lead to a better return for clients than suing immediately. This implies that the decay process modeled here would be observed in spite of the fiduciary duty. Indeed, the fact that securities litigation is almost never observed anywhere in the world in the absence of a class action device is evidence in support of the hypothesis.

The basic model of this paper assumes that some degree of compliance with the law is socially desirable. In the securities field, this is admittedly an empirical question. If compliance is not socially desirable (e.g., no one is harmed), social welfare could be enhanced by prohibiting securities litigation, including class actions (Kraakman, Park, Shavell 1994). Even if some degree of compliance is socially desirable, if the cost of litigation is sufficiently high it may be socially preferable to prohibit litigation (Shavell, 1982). However, if such litigation enhances welfare up to a point, then its disuse or abandonment by victims obviously could be socially undesirable.

[35] Che (1996) shows that the economics of opting out are potentially more complicated than the adverse selection account. Pure adverse selection, leading to positive value claims opting out, is observed in Che's model only when defendants have complete information on plaintiff claims.

6. Conclusion

This model demonstrates that in the multiple victim scenario where the victims have positive expected value claims, the probability of an individual suit collapses with geometric decay as the number of victims increases. This is because the incentive to free ride increases with the number of victims. In spite of this, the incentive to comply with the law does not collapse (as in the negative value scenario), though it is degraded. Undercompliance results, and becomes more severe as the number of victims increases, and compliance is always less than socially optimal. Permissive joinder of plaintiffs, even if it were possible in large numbers, cannot improve on these outcomes. These findings suggest that the class action device may be the only feasible solution to inefficient undercompliance in the multiple victim scenario. However, the same strategic incentives that suggest that the class action may be socially preferable for deterrence purposes also suggest that class actions are inherently vulnerable to terminating in collusive settlements.

Appendix

Proof of Proposition 3: Subtracting marginal liability (5) from marginal social cost (4),

$$(p-q)\{n[v+a^*(c_p+c_d)]-nv[1-(1-a^*)^n]-nc_d\cdot a^*\}$$

$$(p-q)[na^*c_p+nv(1-a^*)^n]$$

Substituting the equilibrium suit probability

$$(p-q)\left[n\left(1-\lambda^{\frac{1}{n-1}}\right)c_p+nv\lambda^{\frac{n}{n-1}}\right]$$

$$(p-q)nc_p. \blacksquare$$

Proof of Proposition 4: If a victim chooses to sue, under joinder, his payoff is:

$$\binom{n-1}{0}a^{n-1}(1-a)^0\left(v-\frac{1}{n}c_p\right)+\binom{n-1}{1}a^{n-2}(1-a)^1\left(v-\frac{1}{n-1}c_p\right)+\cdots+\binom{n-1}{n-1}a^0(1-a)^{n-1}(v-c_p)$$

If he chooses to wait he gets $v[1-(1-a)^{n-1}]$. Equating the two

$$v-c_p\frac{1}{an}\left[\binom{n}{0}a^n(1-a)^0+\binom{n}{1}a^{n-1}(1-a)^1+\cdots+\binom{n}{n-1}a^1(1-a)^{n-1}+(1-\mathrm{a})^n-(1-\mathrm{a})^n\right]=v[1-(1-a)^{n-1}]$$

$$v-c_p\frac{1}{an}(1-(1-a)^n)=v(1-(1-a)^{n-1})$$

The equilibrium strategy $\hat{a}$ therefore satisfies

$$\lambda=\frac{\hat{a}n(1-\hat{a})^{n-1}}{1-(1-\hat{a})^n}$$

where $\hat{a}(n,\lambda)<1$ for all n. For the case where $n=2$, $\hat{a}=2(1-\lambda)/(2-\lambda)$. The equilibrium condition implies that $\hat{a}n$ cannot go to zero or to infinity as n increases.

The solution for λ implies $(1 - \hat{a})^n$ does not go to zero or to one, and $\frac{\lambda}{\lambda + \lim\limits_{n\to\infty} \hat{a}n} = \lim\limits_{n\to\infty}(1-\hat{a})^n < 1$. Rewriting the solution:

$$\left(\frac{\lambda}{n}\right)[1-(1-\hat{a})^n] = \hat{a}(1-\hat{a})^{n-1}$$

Given the foregoing, this final expression implies that $\hat{a}$ goes to zero.■

Proof of Proposition 5: Compliance is less than socially optimal under joinder if

$$(p-q)\cdot n[v+\hat{a}(c_p+c_d)] > (p-q)(1-(1-\hat{a})^n)(nv+c_d)$$

Equivalently

$$(1-\hat{a})^n nv + n\hat{a}(c_p+c_d) > (1-(1-\hat{a})^n)c_d$$

If it is rational to litigate this inequality holds (because the first term on the left is greater than the right hand side). Given that it is rational to litigate, then from Proposition 3

$$1-(1-\hat{a})^n = \frac{\hat{a}[(1-\hat{a})^n]n}{(1-\hat{a})\lambda}$$

Substituting, the inequality holds if

$$(1-\hat{a})^{n-1}\left[(1-\hat{a})nv - \hat{a}\left(\frac{n}{\lambda}\right)c_d\right] + n\hat{a}(c_p+c_d) > 0$$

For this to hold it is sufficient that

$$1-\hat{a} > \frac{\hat{a}c_d}{c_p}$$

Although ambiguous for small n, this inequality becomes stronger as $n\to\infty$.■

Proof of Proposition 6: Marginal liability exceeds marginal social cost if:

$$(p-q)\{n[\pi D + a^*(c_p+c_d)] < nD[1-(1-a^*)^n] - nc_d\cdot a^*\}$$

which is equivalent to $\tilde{\lambda} + \pi < 1$. ■

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