International Review of Law & Economics 73 (2023) 106117

Contents lists available at ScienceDirect

International Review of Law & Economics

journal homepage: www.elsevier.com/locate/irle

The Coase Theorem and the empty core: Inspecting the entrails after four decades

Varouj A. Aivazian [a], Jeffrey L. Callen [b,*]

[a] Department of Economics and Rotman School of Management, University of Toronto, Canada
[b] Rotman School of Management, University of Toronto, Canada

ARTICLE INFO

Keywords:
Coase Theorem
Empty core
Property rights
Institutional arrangements
Farsighted core

ABSTRACT

Ronald Coase pioneered the transaction cost approach to the modern analysis of institutions, contracts, and property rights. We argue that core theory enhances Coase's transaction cost approach by injecting considerations of coalition formation and stability into the analysis. Analysis of coalitional stability also provides additional insights regarding the nature of transaction costs and the efficiency of institutional arrangements when there are such costs. Overcoming the empty core is potentially an important function of contracts, institutions, and property rights. Empty cores complement transaction costs in rationalizing real-world institutional arrangements.

> "We do not do well to devote ourselves to a detailed study of the world of zero transaction costs, like augurs divining the future by the minute inspection of the entrails of a goose." Coase (1981).

1. Introduction

The Coase Theorem was first articulated in Coase's (1960) "Nature of Social Cost" and is reputed to be the most highly cited publication in the field of economics. If for no other reason than that, the debate concerning his theorem deserves attention.[1] The Coase Theorem maintains that in a world of zero transactions costs, resources will be allocated efficiently, independently of initial property rights assignments, because interested parties will find it in their interest to bargain around property rights assignments that militate against efficiency. In addition to zero transaction costs and no wealth effects, the theorem also assumes that except for formulating potential initial property rights, such as the right to pollute or the right not to pollute, the courts do not intervene in the subsequent bargaining process. In particular, the courts do not prescribe the bargaining process that leads to efficiency. For if the courts are allowed to intervene in the bargaining process, they could also prevent bargaining altogether, in which case the Coase Theorem fails to hold. Instead, interested parties are assumed free to reach any agreement that they find to be of mutual interest.

Aivazian and Callen (1981) (hereinafter A-C) provide a counterexample to the Coase Theorem. In their example, efficiency obtains under one set of property rights without the need to bargain. Under the alternative set of property rights, efficiency requires bargaining (recontracting) but because the core of the game is empty, efficiency cannot be guaranteed.[2] In short, the efficient allocation of resources is not independent of the initial property rights assignment, thereby violating both Coasian neutrality and efficiency.

Both in his original paper and in his response to A-C, Coase (1960, 1981) emphasizes that a zero transactions cost environment is of little interest per se but rather represents a baseline from which to rationalize institutional arrangements when transactions costs do matter. Although A-C (1981, 2003) fundamentally agree with this point of view, they also maintain that a core theoretic analysis that abstracts from transaction costs is useful in its own right in rationalizing real-world institutions. With an empty core, institutional arrangements will arise to eliminate situations with bargaining instability and cycling that prevent an efficient solution. Pareto optimality can be achieved when the core is empty by the imposition of constraints on the bargaining process. Considerations of coalitional stability shed further light on the nature of transaction costs when there are more than two agents. As we discuss in Sections 4 and 5, a core theoretic analysis that abstracts from transaction

* Correspondence to: Rotman School of Management, University of Toronto, 105 St. George Street, Toronto, Canada.
E-mail addresses: varouj.aivazian@utoronto.ca (V.A. Aivazian), callen@rotman.utoronto.ca (J.L. Callen).

[1] See Medema (2020) for a recent comprehensive review of the voluminous Coase Theorem literature.

[2] Efficiency in a bargaining context throughout this paper means coalitionally-stable efficiency.

https://doi.org/10.1016/j.irle.2022.106117
Received 29 April 2022; Received in revised form 22 November 2022; Accepted 30 November 2022
Available online 9 December 2022

costs provides a good benchmark for analyzing situations with transaction costs. Thus, the empty core should not be subsumed under transaction costs as it provides additional insights in the presence of transaction costs. Ultimately, the empty core example shows that the nature of the bargaining process and the stability of coalitions matter in rationalizing institutions.

Coase's (1981) reply to A-C appears to have convinced some scholars as evidenced by the fact that the latter continue to write about the Coase theorem but are silent about the A-C counterexample even when it is salient to their analysis. In contrast, other scholars have commented either directly or indirectly on the A-C counterexample, primarily, but not exclusively, in an effort to limit the applicability of the counterexample or to deny the counterexample entirely. A few papers have even picked up on the A-C argument that the empty core rationalizes institutional arrangements independently of transactions costs. The purpose of this paper is to critically review papers that have engaged the A-C counterexample and found it wanting. The essential thrust of this review is to argue that the various criticisms in the literature to the A-C counterexample, including Coase's (1981), fail to do justice to the A-C counterexample –as a number of scholars have noted– and fail to appreciate its importance to institutional economics and law and economics.[3] In addition, this study briefly generalizes the empty core argument to the more recent game-theoretic concept of the farsighted core.[4]

In what follows, Section 2 reviews the original empty-core counterexample without transaction costs. Section 3 discusses Coase's reply. Section 4 reformulates the original A-C model to include transaction costs. Section 5 contrasts transactions cost and the empty core explanations of contractual and institutional arrangements and shows that these explanations are ultimately complementary. Section 6 reviews the subsequent literature on the empty-core argument and the suggested modifications and criticisms of the argument. Section 7 discusses the nature of some of the underlying factors that increase the likelihood of an empty core, especially non-convexities in production, and related evidence. Section 8 briefly discusses relevant non-core notions of coalitional stability, and Section 9 concludes the paper.

2. The original empty core argument without transaction costs

It has long been suggested by the literature that the Coase theorem can be fruitfully framed in terms of cooperative game theory (see, for example, Arrow (1979)). From the perspective of cooperative game theory, the Coase theorem can be interpreted as follows: with zero transaction costs, the grand coalition will always emerge independently of the initial allocation of property rights among the players, whether the superadditive characteristic function of the game has a core or not.[5]

A-C (1981) show that Coasean neutrality and efficiency may fail in a setting with three players and two externalities where there are gains from cooperating to internalize the externalities. They show that the core is empty under one set of property rights, but nonempty under the other. Specifically, when the polluting firms are liable the Pareto efficient outcome emerges, but when they are not liable, the core is empty and negotiations cycle without necessarily converging to the grand coalition (Pareto efficient) outcome or any other specific outcome.[6]

More specifically, the original A-C (1981) example involves two polluting firms (A and B) and a laundry (C), and can be represented in the form of the following normalized characteristic function where V(S) denotes the minimum payoff that any individual firm (S=i) or any coalition (S⊆{A,B,C}) can guarantee itself:

$$V(i) = 0 \text{ all } i = A,B,C; \tag{1a}$$

$$V(A,B) = a,\ V(A,C) = b,\ V(B,C) = c; \tag{1b}$$

$$V(A,B,C) = d \tag{1c}$$

where a, b, c, d are positive constants, and d > a, b, c for superadditivity. The Pareto-optimal outcome corresponds to the grand coalition outcome V(A,B,C).[7] A necessary and sufficient condition for the core to be empty (when A and B are not liable) is[8].

$$d < 1/2(a + b + c) \tag{2}$$

In the original A-C example, condition (2) holds so that the core is empty. Hence, the grand coalition outcome is not guaranteed and specific liability rules matter for efficiency.[9]

[3] Telser (1994, p. 161) writes "The Coase Theorem needs much repair when there is an empty core… Coases's elaborate analysis in his comment (1981) fails to come to grips with the issues raised by this example…". In a similar vein, Hurwicz (1995, p. 64) writes: "What do the Aivazian-Callen examples prove? Primarily, I believe, that it would be desirable to have a statement of a Coase Theorem that is applicable to such situations. Coase's (1981) comment in response to Aivazian and Callen (1981) does not seem to have filled the gap."

[4] In this study and in the literature cited therein, the worth of a coalition depends solely on the members of the coalition. The latter standard cooperative game theory framework stands in contrast to what has become known as cooperative games with externalities in which the worth of a coalition may be affected by other coalitions. In cooperative games with externalities, players attempting to deviate from the grand coalition will consider various reactions of the other players and coalitions. This diversity of conjectures yields many potential concepts of the core such as the optimistic core and the pessimistic core (Abe and Funaki, 2017). Be as it may, in cooperative games with externalities, efficiency is generally not sufficient for the non-emptiness of the (optimistic) core even for superadditive games, so that counterexamples to the Coase theorem are, if anything, even more endemic to cooperative games with externalities. See Hafalir (2007) for an example of a cooperative game with externalities such that superadditivity fails to yield the efficiency of the grand coalition. The Coase Theorem would fail for this example.

[5] See Telser (1994) for a good discussion of the theory of the core. With a superadditive characteristic function, the returns to any coalition are no less than the sum of the returns to its non-intersecting sub-coalitions.

[6] Aivazian and Callen (2019) provide a brief summary of the Aivazian and Callen (1981, 2003) papers.

[7] The characteristic function will likely differ under different property rights because what each coalition can guarantee itself depends on the prevailing property rights arrangements (Shubik, 1984, Ch. 19). In our example, the characteristic function when A and B are not liable is:
V(A) = $3000; V(B) = $8000; V(C) = $24,000;
V(A,B) = $15,000; V(A,C) = $31,000; V(B,C) = $36,000;
V(A,B,C) = $40,000.
When A and B are liable the characteristic function becomes:
V(A)' = V(A) – min{V(A), V(A,B,C) – V(B,C)} = 0;
V(B)' = V(B) – min{V(B), V(A,B,C) – V(A,C)} = 0;
V(C)' = V(C) + min{V(A,B,C) – V(C), V(A,B)} = 39;
V(A,B)' = V(A,B) – min{ V(A,B), V(A,B,C) – V(C)} = 0;
V(A,C)' = V(A,C) + min{ V(B), V(A,B,C) – V(A,C)} = 39;
V(B,C)' = V(B,C) + min{ V(A), V(A,B,C) – V(B,C)} = 39;
V(A,B,C) = 40.
The conditions for the core become:
$X_A \geq 0$; $X_B \geq 0$; $X_C \geq 39$;
$X_A + X_B \geq 0$; $X_A + X_C \geq 39$; $X_B + X_C \geq 39$;
$X_B + X_C + X_C = 40$.
The core is non-empty since there are values of X_A, X_B, X_C that satisfy these conditions.

[8] See Aivazian and Callen (2003, footnote 12).

[9] Shubik (1983, p. 150) writes: "A game that has a core has less potential for social conflict than one without a core, since every cooperative or collusive effective demand can be granted. A coreless game, on the other hand, must leave at least one coalition unsatisfied, that is, short of its potential. At least one group of players can always do better by dropping out and going it alone. If they try it, though, another group will be able to make a better offer to some of the dropouts in a new alignment, and the bargaining may continue at great length." Bernholz (1997) suggests that the empty core is isomorphic to cyclical social preferences.

3. Coase's reply

Coase (1981) raises three issues that he believes makes the A-C counterexample irrelevant. First, Coase argues that starting from an (inefficient) allocation involving two-party agreements, endless re-contracting will result in the parties reaching a specific (but inefficient) allocation in the limit, provided gains are divided equally among the two-party participants in each bargaining round. As consequence, because this specific inefficient allocation would be dominated by the grand coalition, the grand coalition solution would necessarily obtain. Second, recognizing that the grand coalition could still be unstable, because any two parties would have an incentive to break away from the grand coalition if they could do better on their own, Coase further argues that the parties would agree to penalty clauses that would make it unprofitable to break away from the grand coalition. Third, Coase argues that, in any case, the empty core arises because of the zero transactions cost assumption and a world without transactions costs is fundamentally uninteresting.[10]

None of Coase's three arguments are cogent. First, re-contracting that arises from the empty core does not devolve on any two specific parties. Re-contracting involves all three parties so that the assumption that two will re-contract endlessly to a specific solution is ad hoc in the extreme. For example, two parties may re-contract for 3 rounds but then the third party will enter and draw away one of the original two parties for a different set of re-contracting rounds, say for a further 5 rounds and so on. Moreover, Coase's assumption that the two parties will always divide profits equally at each bargaining round is equally ad hoc. In any case, nothing is really added by Coase's limiting argument. The A-C counterexample is *constructed* so every two-party coalition earns a maximum that is less than what the grand coalition earns. Clearly, the grand coalition dominates any two-party coalition but nevertheless, the core is empty when bargaining ensues and an efficient solution cannot be guaranteed. Second, penalty clauses may indeed mitigate the empty core, but penalty clauses are inconsistent with the underlying assumptions of the Coase Theorem. Moreover, who would enforce these penalty clauses even if the parties agreed to them at some point in the bargaining process? In any case, if inefficiencies due to the empty core can be overcome via constraints on the bargaining process and penalty clauses then that implies that empty core considerations may rationalize specific contractual provisions.[11] In other words, the empty core and the bargaining process, no less than transactions costs, are crucial for understanding real world institutional arrangements.

Third, A-C (2003) extend their counterexample to a world of transactions costs and show that very reasonable convex cost technologies *exacerbate* the problem of the empty core. Just as in the case of zero transactions costs, under one liability rule efficiency obtains whereas under the other liability rule bargaining and an empty core ensues. Thus, Coase's reply simply fails to come to grips with the A-C counterexample. We briefly review the A-C model with transaction costs next.

4. The empty core and transaction costs

A-C (2003) modify the original A-C (1981) example to include transaction costs[12]. These costs are associated with negotiations to internalize the externality for the case where the polluting firms are not liable. A-C assume a transaction cost structure such that the costs of forming a coalition are (strictly) convex in the number of parties in the coalition.[13] This implies that coalition formation costs increase at an increasing rate with the number of members in the coalition. This seems reasonable since the number of warranted communications channels to obtain agreement among coalition members is also convex in the number of coalition members. They consider the following convex cost function:

$$C(X) = \begin{cases} X^k \text{ for } X > 1 \\ 0 \text{ for } X = 1 \end{cases} \tag{3}$$

where X is the number of firms in the coalition and k is a parameter, $k > 1$. Thus, the characteristic function of the negotiations becomes.

$$V(i) = 0 \text{ all } i = A,B,C \tag{4a}$$

$$V(A,B) = a - 2^k,\ V(A,C) = b - 2^k,\ V(B,C) = c - 2^k \tag{4b}$$

$$V(A,B,C) = d - 3^k \tag{4c}$$

A necessary and sufficient condition for the core to be empty with these transaction costs is:

$$d - 3^k < 1/2\ (a - 2^k + b - 2^k + c - 2^k) \tag{5}$$

or,

$$d + 1/2\ [3(2^k) - 2(3^k)] < 1/2\ (a + b + c) \tag{6}$$

Noting that.

$$1/2[3(2^k) - 2(3^k)] < 0 \text{ for } k > 1, \tag{7}$$

and comparing inequalities (2) and (6), yields the following two conclusions. First, if the core is empty without coalition formation costs, then it is necessarily empty with such costs. Second, even if the core is not empty in the absence of transaction costs, such costs can force an empty core.[14]

5. Transaction costs versus empty core arguments

In the foregoing, we labelled as transaction costs the direct costs of negotiating agreements. However, one may choose to use an expanded notion of transaction costs and label as transaction costs the costs associated with the empty core and cycling, including the opportunity cost of delayed agreement or of settling on a sub-coalition rather than the grand coalition. While we disagree with such an expanded interpretation of transaction costs, one should nevertheless recognize that such costs and the contractual provisions for overcoming them are due to the empty core, and that is a central message in A-C (1981, 2003).

[10] Coase writes, "I would not wish to conclude without observing that, while consideration of what would happen in a world of zero transaction costs can give us valuable insights, these insights are, in my view, without value except as a step on the way to the analysis of the real world of positive transaction costs. We do not do well to devote ourselves to a detailed study of the world of zero transaction costs, like augurs divining the future by the minute inspection of the entrails of a goose." Coase (1981), page 187.

[11] Shubik (1983, p.151) writes, "In a coreless game then, some constraints on coalitional activity must be operative in the society or else they will be engendered during the play of the game." Telser (1994) discusses the role of constraints on the bargaining process to resolve an empty core and generate efficient outcomes. Bernholz (1997) provides a similar rationale for binding contracts.

[12] The discussion in this section is based on Aivazian and Callen (2003, pages 4–5).

[13] While convexity is not necessarily more reasonable than say concavity, it does show that there are non-trivial situations for which an empty core obtains in the presence of transaction costs.

[14] See A-C (2003) p. 291–292, who write, "It is wrong to conclude, therefore, that once transaction costs are introduced, then the problem of the empty core disappears and a Pareto optimal solution obtains. Rather, in such circumstances, negotiations may break down more quickly and which specific coalition structure (the grand coalition or a proper sub-coalition) obtains cannot be specified a priori. Even if transaction costs were to force an equilibrium, nothing ensures that the equilibrium is Pareto optimal." For a more realistic dynamic model of the core with transactions costs, see Graham et al. (1972).

Medema (2020) discusses yet a broader conception of zero transaction costs and writes: "A zero transaction cost world, so conceived, is one without a time dimension, where all inefficiencies are resolved instantaneously, regardless of the number of agents involved" (p. 1070). Medema cites the argument of Ralph d'Arge (1973, p.558) and writes, "if transaction costs were zero, there would be no externalities or other forms of market failure to which to apply the Coase theorem since they would have been internalized through bargaining before manifesting themselves" (p.1070). It is worth noting that the properties of the zero transactions cost environment highlighted by Medema are similar to those of a "complete market" economy with full information and where rights over all future contingencies are fully defined and every agent makes one life-long choice in advance. Time plays an artificial role in this setting as all decisions collapse to the present. See for example Hahn (1971).

One view of the nature of the foregoing broadly conceived zero transaction cost setting is that externalities, bargaining, and empty core problems will not exist in that environment; that these can only emerge when transaction costs are positive. An alternative view, which we find more compelling, asserts that externalities, bargaining, and empty core problems would not necessarily disappear under this broader conception of transaction costs even if these costs are absent. If transaction costs are zero and players have full information ex ante— about their strategic positions and the structure of the potential ex post payoffs —then the (ex ante) bargaining will also be subject to the empty core problem. A collectively rational outcome is therefore not assured. Specifically, consider the ex ante bargaining process in our example in this zero transaction cost setting. Efficiency dictates that the rights be allocated to player C, but bargaining will not necessarily achieve that allocation as it will have an empty core so long as players A, B, C have full information about the structure of their potential ex post payoffs. Clearly the empty core is not just a manifestation of transaction costs. Ex ante or antecedent transaction costs may generate an empty core but are not a necessary condition for an empty core. Contractual provisions may overcome the empty core but it is unclear whether they will emerge through voluntary and decentralized ex-ante negotiations. Dixit and Olson (2000) analyze a similar problem in a two-stage game involving the provision of a public good. They show that under zero transaction costs and full information at the ex ante stage, free rider problems undermine the possibility of achieving, through ex ante negotiations, optimal rules for the provision of the public good. They also show that collectively rational or optimal rules would require involuntary or coercive mechanisms.

Medema (2020, 1072–1073) correctly points out that in a zero transactions cost environment with fully defined rights, agents must be compensated, through negotiations if there is an alteration of their rights. The A-C model pertains to those negotiations and shows that they may not necessarily yield efficient outcomes. The A-C example assumes zero transaction costs, complete property rights, complete information and, as we show below, farsightedness, and yet the core is empty.[15] The intuition is straightforward. The empty core implies that any potential agreement is dominated or undermined by another potential agreement which in turn is dominated by yet other potential agreements, and so on. This bargaining process entails offers and counteroffers among agents that in principle can go on indefinitely. The process simply does not resolve itself into a binding agreement (contract) that satisfies *both* individual and collective rationality. The implication is not that contracts keep being violated but rather that contracts satisfying rationality requirements are not reached. The possibility of endless bargaining and the ensuing inefficiencies potentially induce the emergence of arrangements, including contracts with penalty clauses, which overcome the empty core and generate efficiency.

The A-C example does not imply agent irrationality. Instead, it raises the possibility that in some circumstances it may be difficult to fulfill the requirements of both individual and collective rationality. While the possibility of endless bargaining could undermine rationality, empty core situations will induce arrangements that mitigate cycling to generate efficiency. Indeed, the economic merit of the A-C analysis is to highlight the role of specific contractual and institutional arrangements that are warranted to overcome the empty core and generate rational and efficient outcomes. Note also that in his reply to A-C, Coase (1981, p.187) argues that penalty clauses in agreements would overcome the empty core problem. Indeed, specific contractual provisions could mitigate cycling and help induce efficiency. The ultimate importance of the A-C example is to rationalize such contractual provisions.

Allen (2015) argues that zero transaction costs are equivalent to complete property rights. Allen also argues that all factors that mitigate Coaseian efficiency and irrelevance should be termed transaction costs. Presumably, scholars who agree with Allen would label the A-C empty core problem as due to transaction costs. We believe that a core-theoretic analysis of Coaseian bargaining has an important bearing on Coaseian irrelevance and efficiency in its own right, and, importantly, serves to explain specific institutional arrangements that would mitigate empty core problems. To the extent that the empty core generates unique institutional arrangements to help ensure efficiency, it is useful to keep considerations of the empty core in rationalizing real world institutions distinct from transaction costs.

The usefulness of distinguishing between transaction costs and the empty core is illustrated by considering the optimality of property rules versus liability rules, discussed originally by Calabresi and Melamed (1972). Posner (1998, p. 77) writes: "In conflicting-use situations in which transaction costs are high, the allocation of resources to their most valuable uses is facilitated by denying owners of property an injunctive remedy against invasions of their rights and instead limiting them to a remedy in damages…But where transaction costs are low, injunctive relief should normally be allowed as a matter of course…". However, as A-C (2003, footnote 16) point out, in circumstances where the core is empty, a liability rule may be superior to a property rule even if transaction costs are low since bargaining will not necessarily generate efficient outcomes. In other words, a property rule, under low transaction costs, may be subject to an empty core potentially limiting its advantage over a liability rule.

6. Other critiques, modifications and extensions

6.1. Mueller; Bernholz; Guzzini and Palestrini; Gonzalez, Marciano and Solal; and Zhao

Mueller (2003, p. 32) argues that the empty-core problem in A-C (1981) stems from the attempt to simultaneously resolve, via bargaining, multiple externalities with the help of but one liability rule. He points out correctly that if bargaining were sequential where negotiations between any two agents are independent of those among other pairs, the core would exist and Pareto efficiency achieved. In effect, Mueller has imposed constraints on the bargaining process to guarantee efficiency. Moreover, Mueller's sequential scheme is problematic if agents have more foresight. As A-C (2003, p. 295) point out, "An agent contemplating entering into a bilateral agreement recognizes that the agreement may foreclose a possibly higher payoff in the future; agreeing early removes future bargaining options. The sequence in which bilateral bargaining occurs may affect an agent's allocation and, hence, the agent's incentives to enter into a particular bilateral agreement in the sequence; this may once again generate a tension between individual and collective rationality and the problem of the empty core remains."[16]

[15] With the extended transactions cost concept, complete information is also important in yielding the A-C counterexample. Indeed, the farsighted core analyzed below is a complete information environment in that participants are able to anticipate all potential deviation possibilities in the bargaining process, and still the A-C empty core counterexample applies.

[16] In essence, Mueller's conjecture is incorrect from the perspective of the farsighted core. For the latter, see below.

Note that in his reply to A-C, Coase (1981, p. 187) also imposes constraints on bargaining and contracts when he asserts that the empty core would be resolved if contracts "…have a time dimension and parties not adhering to the terms of the agreement within that time would be subject to a penalty". Coase goes on to write, "If such provisions were included in the contract, A, B, and C would be able to enjoy infinitely higher incomes and they would certainly have no objection to their inclusion, if, without it, there would be "endless recontracting."

Indeed, such provisions may eliminate the instability of the empty core and help to attain efficiency, but Coase's assertion undermines the Coase Theorem. As A-C (2003, p. 292) point out, "In the standard Coase scenario zero transaction cost environment, penalty clauses, time limits and other contractual features are simply irrelevant. In contrast, an empty core frustrates Pareto Optimal exchanges by eroding the value of the exchange opportunity through either prolonged recontracting or by settling on a non-optimal outcome. Therefore, the empty core does indeed rationalize the use of penalty clauses in contracts to attain Pareto Optimality."

Bernholz (1997) demonstrates the A-C argument and their 1981 results in a non-game-theoretic setting with more than two agents. He then develops a generalized Coase theorem where problems of instability are resolved through binding and enforceable contracts. Guzzini and Palestrini (2009), in a similar fashion to Bernholz (1997), introduce frictions into the Coasian bargaining process and show that these could mitigate the empty core problem. Guzzini and Palestrini's frictions or transaction costs pertain to an agent's history of contract breach as agreements are made and then broken; that is, they concern the adverse reputation and reliability effects engendered by the breaking of agreements. They show that such informational frictions can mitigate the empty core problem. In their setting, there is an asymmetric information dimension to the problem and also learning (about agent reliability). However, this argument does not really undermine the original A-C argument. If there is asymmetric information, reputation concerns may limit the number of bargaining rounds and possibly lead to a non-empty core (where the characteristic function reflects such "transaction costs"). Alternatively, in their asymmetric information setting, arrangements may evolve among the participants to give greater structure to the bargaining process and limit the number of bargaining rounds. Nevertheless, the grand coalition solution cannot be guaranteed.

Gonzalez et al. (2019) use (axiomatic) cooperative game theory to examine the Coase Theorem and the issue of the core. They extend the A-C example to cases involving a profit-generating polluting firm and a finite number of non-competing victims suffering pollution damage. The authors introduce a set of mappings of rights that describe the legal structure of negotiations among agents. A mapping of rights either prevents a coalition from negotiating, or the coalition is allowed to form and negotiate an agreement. They propose three properties for mappings of rights: core compatibility which requires that the core associated with any social cost problem is non-empty; Kaldor–Hicks core compatibility which requires that a payoff vector in the core ensures a non-negative payoff to each agent; and no victim can individually veto an agreement reached by the rest of the society.

The authors provide two main results. Their Proposition 1 shows that the set of mapping of rights satisfies core compatibility if and only if rights are assigned either to the polluter or, alternatively, to all the victims of pollution where the coalition of all of the victims is the only entity with the right to sign a binding agreement with the polluter. Their proposition 1 is consistent with the A-C example. In the A-C example, if the laundry has the property rights a core solution emerges as the polluting factories shut down. In contrast, if the polluting factories in the A-C example are assigned the property rights and are constrained to act as one entity in negotiations with the laundry, then a core solution emerges where the factories shut down and the laundry continues its operations; thus, an agreement with core allocations would emerge in this case as well. Note that in the latter case the grand coalition solution is imposed on the participants so that the core necessarily exists—imposing the grand coalition just removes the sub-coalition constraints that are at the heart of the empty core in the A-C example. Proposition 2 shows that, in all other situations, it is possible to find examples of social cost problems to which one can naturally associate a cooperative game whose core is empty so that Coasian efficiency cannot be guaranteed. Moreover, because not all mappings are core compatible, Coasian neutrality need not obtain, thereby generalizing the A-C counterexample. Importantly, Gonzalez et al. (2019) also show that the empty core arises even when significant structure is imposed on the bargaining process, namely, allowing coalitions, including the grand coalition, to sign binding agreements.[17]

Techer (2021) further extends Gonzalez et al. (2019) to allow for a set of mapping of rights that depend on the polluter activity level such as in the case of pollution quotas. Polluters are assumed to have a finite number of pollution activity levels so that, if participants choose to negotiate in a coalition, they also need to choose among different activity levels. Unlike standard cooperative games where participants either join a coalition and fully participate in or reject negotiations, quotas require multi-choice games and a more comprehensive definition of the core. Subject to additional assumptions compatible with multi-choice games, Techer (2021) shows that any cooperative game in which a quota is imposed will yield core compatibility provided the grand coalition solution is possible. Alternatively, core compatibility obtains if the mapping assigns rights exclusively to the victims (laundry). Otherwise, core compatibility cannot be guaranteed.

Zhao (2018b) proposes a solution to the empty core counterexample of AC (1981). Inter alia, Zhao (2018b) shows that if the three firms in the A-C counterexample agree to arrange and sequence production in a specific fashion, subject to the same *sub-coalitional* resource constrains, optimal production by all firms will exceed "d"—see Eq. (2) above–yielding a non-empty core. In other words, operations by sub-coalitions can be sequenced in such a way that, in total, they produce more than the grand coalition (monopoly) solution yielding a non-empty core. But this assumption is counter-intuitive in an environment of zero transactions costs. How is it possible that firms operating separately can generate more profits in total than what they can produce operating in tandem? This may be possible in a world with transaction costs, although quite unlikely, to the extent that production coordination in a monopoly is more costly than production coordination outside of the monopoly.[18] In effect, Zhao removes the constraint of the grand coalition, namely, Eq. (1c), thereby *forcing* core existence.

6.2. The Robson Critique and the Crettez follow-up

Using the A-C counterexample as his backdrop, Robson (2014) argues that the empty core will not occur often. Adopting the convention that all bargaining payoffs are equally probable, he shows that the empty core in the context of the A-C counterexample occurs only 1/6 of the time. In addition, he shows that there are concave transactions cost structures for which the core of the A-C counterexample is non-empty. Similar to Coase's (1981) assumption that re-contracting profits are

[17] Gonzalez et al. (2019) approach the Coase Theorem from an axiomatic normative perspective in contract to A-C (1981) who view the Coase Theorem from an essentially positive perspective (albeit in a world of zero transactions costs). Although the focus of former's approach is deriving conditions under which the Coase Theorem is valid, they also provide conditions for which the Coase Theorem fails. Unlike the counterexample approach of A-C that focuses on the Coase Theorem's implications, the approach by Gonzalez et al. (2019) tends to focus on an analysis of the underlying conditions that would either mitigate failure or lead to failure. We view these two approaches as complementary.

[18] The Zhao (2018b) paper is insightful on other grounds but not as regards the A-C (1981) empty core argument.

always equally divided, the assumption that all bargaining payoffs are equally probable is just as ad hoc. Furthermore, while non-empty cores are more likely to arise with concave transactions costs, empty cores are more likely to arise with convex cost technologies. Moreover, as has been noted by a number of scholars—see further below–empty cores are likely to be ubiquitous for non-convex production technologies.

Robson (2014) focuses solely on efficiency. Crettez (2020) extends Robson's approach to show that both efficiency and neutrality are unlikely to hold simultaneously. Under the assumption that all outcomes in the Aivazian-Callen example are uniformly distributed, Crettez (2020) shows that the probability that both efficiency and neutrality hold simultaneously is only 3/8.

6.3. The Ellingsen-Paltseva Critique

Ellingsen and Paltseva (2016) (hereinafter E-P) analyze the Coase theorem through the lens of non-cooperative contract theory. In an oblique reference to A-C, E-P maintain that A-C did not find a counterexample to Coase. To quote (p.36): "An early strand of cooperative analysis had revealed that many cooperative games have an empty core. This finding was interpreted to mean that efficiency is not generally implied by voluntary negotiations; see especially Aivazian and Callen (1981). However, as pointed out by Coase (1981) a non-prediction is different from a failure prediction. Only if the prediction is that the outcome might be inefficient will the Coase theorem be overturned."

The E-P critique of A-C is somewhat opaque but it seems to be that an empty core does not necessarily lead to inefficiency. After all an efficient solution could obtain even when the core is empty. If this interpretation of E-P is correct, they seem to be missing the point of the A-C counterexample. The issue is not the empty core per se—the empty core was well understood prior to A-C. Rather, the Coase Theorem is not only about efficiency but also about neutrality, the symmetry of resource allocation between the two sets of property right regimes. The Coase theorem maintains that efficiency will obtain *irrespective* of initial property rights. In contrast, the A-C counterexample shows that while one set of initial property rights yields an efficient solution without bargaining, the other set of property rights leads to bargaining in an empty core environment. In the latter case, not only does neutrality fail but efficiency cannot be guaranteed so that the Coase Theorem fails. Moreover, as discussed further below, the Coase Theorem also fails for coalitional stability concepts other than the core, and, at least for one such concept, the grand coalition turns out to be unstable whereas some sub-coalitions are stable, so that efficiency is guaranteed to fail.

Regarding the E-P analysis itself, we would argue that it is essentially unrelated to the Coase Theorem despite their exaggerated claim to the contrary. First, non-cooperative game theory models tend to impose ad hoc structures on bargaining processes.[19] The model by E-P is especially problematic in that it imposes a highly structured 4-stage contractual bargaining model on the Coase theorem, whereas the Coase Theorem is presumed to hold for any bargaining process.[20] It is precisely because of the ad hoc bargaining engendered by non-cooperative game theory models that makes cooperative game theory modeling of the Coase Theorem preferable. Second, the E-P analysis is focused on the details of the contracting process and contract enforcement by the courts. But, as we pointed out above, the Coase Theorem assumes that courts set initial property rights and are subsequently uninvolved.[21] Of course, with transactions costs, we may want to have courts involved in the bargaining process in order to help attain efficiency. However, in the Coase base line environment, contractual terms will be accepted and adhered to by the parties involved only to the extent that it is in their interest to do so. The minute one party (in a two-party coalition) is offered more by a third party, the initial contract proposal will not be signed and can be abrogated at no cost or penalty to the parties involved.[22] Moreover, as Gonzalez et al. (2019) show, empty cores arise even when coalitions can ensure binding agreements.

6.4. Empty core and Coasean economics

While the studies by Bernholz (1997), Mueller (2003), Guzzini and Palestrini (2009) and others seem to be aimed at generalizing and "rescuing" the Coase theorem from the A-C counterexample, their analyses ultimately demonstrate the value of core theory (and of empty core considerations) in rationalizing specific contractual and institutional arrangements as means of overcoming impediments to the attainment of efficiency engendered by the empty core. Even Coase's reply to A-C can be viewed in that light, as he points out how constraints on the process of contracting and re-contracting can help overcome bargaining difficulties that impede the attainment of efficiency due to the empty core. In fact, the A-C core theory approach is ultimately very Coasean in that it emphasizes the important role of negotiations over the transfer of property rights (in situations with externalities). But at the same time, the A-C analysis illustrates that the Coasean bargaining road is sometimes difficult for reasons other than simply transaction costs. The A-C analysis demonstrates that empty core considerations have a logic of their own and should not be subsumed under the rubric of transaction costs.

7. Production non-convexities

The discussion by A-C (1980, 2003) focuses on a counterexample involving two externalities in production (pollution). One might be tempted to argue that their counterexample is contrived and that in the "real world" empty cores are uncommon. However, as shown by Bitlingmayer (1982), Pirrong (1992), Scarf (1986), Sjostrom (1989), and Telser (1994) empty cores tend to arise whenever there are indivisibilities in production such as avoidable costs, set up costs and team synergies.[23] Not only are such production non-convexities common fare but it is in fact difficult to conceive of realistic production technologies that are convex.

To see why non-convexity matters to the empty core, consider a simple example based on Telser (2007) involving the production of a good for which there are no other available substitutes. A production team is comprised of one to three individuals any two of whom working

[19] One could argue that cooperative and non-cooperative models are fundamentally non-comparable in that, in contrast to the latter, the former abstract from the exact steps in the bargaining process. As noted by Aumann (1987) "... when one does build negotiation and enforcement procedures explicitly into the model, then the results of a non-cooperative analysis depend very strongly on the precise form of the procedures, on the order of making offers and counter-offers and so on.…problems of negotiation are usually more amorphous; it is difficult to pin down just what the procedures are. More fundamentally, there is a feeling that procedures are not really all that relevant; that it is the possibilities for coalition forming, promising and threatening that are decisive rather than whose turn it is to speak." (p.55). See also Chwe (1994) on this issue. The important point from our perspective is that the results of non-cooperative analysis depend very strongly on precise bargaining form assumed. The Coase Theorem in our opinion abstracts from the precise bargaining form and thus cooperative game theory is more relevant in this context.

[20] Similarly, in other non-cooperative models, Anderlini and Felli (2001, 2006) and Lee and Sabourian (2007) impose a highly structured alternating offers Rubinstein (1982) model on the bargaining process when analyzing the Coase Theorem and transactions costs. In their case, there are only two parties and coalitional bargaining is not an issue.

[21] Of course, courts could costlessly enforce contracts but in the Coase environment courts are irrelevant except for setting initial property rights.

[22] By and large, the focus of E-P's analysis is on the issue of free-riding, similar to the analysis by Dixit and Olsen (2000).

[23] However, see Zhao (2018a), who contests the evidence in these studies of non-empty cores for industries with non-convex technologies.

together can produce a maximum payoff value of 100. A third participant adds no more value and each individual alone produces nothing (a production indivisibility). The payoff is distributed solely to the participants who in fact worked. It is easy to show that the core of the game is empty if bargaining among the three parties is unconstrained by the legal system. The empty core is generated both by indivisibilities in production and by the absence of any legal constraints on the bargaining process. The absence of legal constraints on the bargaining process creates (excessive) competition among all potential coalitions which, in turn, helps to generate an empty core whenever there are non-convexities. However, should the legal system mandate that at least one member of the production team must be a licensed engineer, and only one of the participants is in fact a licensed engineer, the core is no longer empty and the good is produced. By requiring a licensed engineer, the legal system limits competition among the potential coalitions, yielding a non-empty core despite indivisibilities in production.

When the legal system requires a licensed engineer to produce, thereby limiting competition among potential coalitions, efficiency obtains. In contrast, if the legal system allows for unconstrained bargaining, the core is empty and efficiency is no longer guaranteed. This example is interesting because it illustrates the causes for the non-empty core as well as a mechanism for its resolution. The causes are indivisibilities in production and unconstrained competition among the potential participants to engage in production. Transactions costs are not the issue regarding this licensing example, the issue is the empty core. In this case, the resolution of the empty core involves the imposition of constraints on the bargaining process.

Empirical studies have found ample evidence of non-empty cores for industries with non-convex technologies such as the ocean liner shipping industry (Pirrong, 1992; Sjostrom, 1989), and the cast iron pipe industry (Bittlingmayer, 1982). In the latter cases, institutional arrangements arise to mitigate the empty core. For example, these studies rationalize commonly found contractual industry constraints, such as cartel-type arrangements in the ocean liner shipping industry to limit competition, as mechanisms for resolving the problem of the empty core. In a similar if more theoretical vein, Ambec and Kervinio (2016) use core theory to analyze the cooperative provision of globally beneficial but locally harmful economic benefits such as landfills, waste treatment plants and polluting utilities that also involve non-convexities in production. In particular, they provide comparative statics for when the Coase theorem is less/more likely to fail because of non-empty cores involving these so-called "Not in My Back Yard" phenomena.

Experiments have also generated evidence regarding the importance of the empty core in bargaining situations. Aivazian, Callen and McCracken (2009) investigate the Coase efficiency result experimentally in a bargaining game in which the final allocation of payoffs differ in terms of whether the core exists and in the initial allocation of property rights among the players. Their experimental results indicate that the existence of the core is an important determinant of negotiation outcomes. They find that when the core is empty and property rights are ill-defined, Coasean efficiency breaks down. In particular, the number of non-Pareto-optimal agreements and negotiation rounds with cycling are significantly larger when the core is empty than when it exists, particularly when property rights are ill-defined.[24]

8. Non-core coalitional stability

Why focus on the core? After all, game theory offers many bargaining environments (solution concepts). A-C's initial focus on the core is motivated by three thoughts. First, the core imposes few if any constraints on the bargaining process in contrast to many other solution concepts (especially as regards non-cooperative games but not only). If the Coase Theorem is to be viewed as a Theorem and not a tautology, one must necessarily employ a bargaining environment in which agents can costlessly recontract around legal liability rules and in which agents are free to organize themselves as they wish.[25] Second, the core generalizes the notion of competition, which is consistent with costless bargaining (Aumann, 1985). Indeed, quite a few authors have imposed a competition assumption on the Coase Theorem.[26] Third, the core underlies much of general equilibrium theory and the fundamental welfare theorems. Since the Coase Theorem is essentially a general equilibrium statement, the core should be a meaningful environment in which to analyze the validity of the Coase Theorem. In fact, one might have surmised that if anything the core bargaining environment biases towards finding the Coase Theorem because one would have expected that in a core bargaining environment with a superadditive characteristic function, efficiency naturally follows; but as A-C's counterexample shows, it does not.

As it turns out, similar problems regarding the Coase Theorem engendered by the empty core arise under alternative (non-core) notions of stability. This is important for two reasons. First, it generalizes the potential failure of the Coase Theorem to other perhaps even broader bargaining environments (such as bargaining sets) and is not a phenomenon that is just particular to the core.[27] Second, as noted above, there are those who would argue that A-C example is insufficient to invalidate the Coase Theorem because efficiency might obtain when bargaining ensues under an empty core if only by happenstance. After all, inefficiency is not "guaranteed" when the core is empty.

Note that for the Coase Theorem to obtain, no coalition except the grand coalition can be stable; otherwise, a Pareto optimal allocation may not emerge. Aivazian, Callen, and Lipnowski (1987) extend the Aivazian-Callen (1981) example to Aumman and Maschler (1964) bargaining set notions of coalitional stability and show that while a Pareto-Optimal allocation of resources obtains for one liability rule, a non-Pareto Optimal allocation may well emerge for another liability rule that involves bargaining. In fact, they show that under one notion of bargaining set stability, every coalition *but* the grand coalition is stable, "guaranteeing" inefficiency and completely undermining the Coase Theorem.[28]

One might argue that both the core and bargaining sets are essentially static myopic concepts and in a dynamic setting with farsighted coalition participants, efficiency will necessarily obtain as long as bargaining is costless.[29] More specifically, in an environment in which coalition participants are farsighted, it is possible that no participant will deviate (move) from one coalition to another before evaluating what the deviation implies for potential future deviations ad infinitum. For example, in an Aumann-Maschler bargaining set environment, although participants evaluate deviations (called objections in Aumann and Maschler (1964)) from a coalition and further deviations from the latter (counter-objections), but that is where the story ends. In a farsighted environment, on the other hand, each participant would surely evaluate deviations from deviations from deviations, and so on, yielding the

[24] In two-person experimental settings devoid of coalition behavior, Bar-Gill and Engel (2016) find that the Coase theorem tends to hold even when property rights are ill-defined. By contrast, Friesen et al. (2022) find that the Coase Theorem tends to fail when initial property rights are ill-defined.

[25] Imposing a game theoretic solution for which the Coase Theorem necessarily holds results in a tautology.

[26] See Stigler (1966, p.113), Regan (1972), and the review paper by Chipman (1998) among others.

[27] There is experimental evidence suggesting that when the core is empty bargaining will yield payoffs close to those of the bargaining set. See, for example, Maschler (1978) and, more broadly, Kahan and Rapoport (1984).

[28] For a counter-intuitive (by the author's own admission) but interesting argument that makes the Coase theorem compatible with bargaining set subcoalition stability, see Gangopadhyay (2000).

[29] Harsanyi (1974) was the first to note the myopic nature of bargaining sets and the core. The concept of farsighted coalitional stability was developed primarily by Chwe (1994).

potential outcome that the grand coalition is necessarily stable by comparison to sub-coalitions.[30]

More importantly, what about the empty core argument? The core too is myopic in the sense that participants in the game deviate from the existing coalition only if there is an immediate potential benefit by doing so. But what if the participants potentially deviating from one coalition to another are sufficiently far sighted to see that this deviation will lead to a further subsequent deviation and that in turn will ultimately lead to more deviations? If these participants take into account all potential deviations, would that not lead eventually to a grand coalition in which all participants benefit the most? In other words, would not the core of this farsighted game exist (the farsighted core) even though the standard core does not exist? Despite the apparent cogency of this argument, the answer is negative. In fact, it is quite straightforward to show that the farsighted core is necessarily a subset of the standard core so that if the core is empty, the farsighted core will also be empty (Beal et al., 2008). Thus, the A-C (1981) empty core counterexample generalizes to the farsighted core as well.

9. Conclusion

Transaction costs have been central to the modern analysis of institutions and property rights structures. Core theory enhances the transaction cost approach by injecting considerations of coalition formation and stability into the analysis. Overcoming the empty core is an important function of contracts, institutions, and property rights.[31] Thus, empty cores complement transactions costs in rationalizing real-world institutional arrangements.

Author statement

We wish to thank the reviewers of this Journal and the Co-Editor for their constructive comments.

Data Availability

No data was used for the research described in the article.

References

Abe, T., Funaki, Y., 2017. The non-emptiness of the core of a partition function form game. Int. J. Game Theory 46, 715–736.
Aivazian, V.A., Callen, J.L., 1980. Corporate leverage and growth: the game- theoretic issues. J. Financ. Econ. 8 (4), 379–399.
Aivazian, V.A., Callen, J.L., 1981. The Coase Theorem and the empty core. J. Law Econ. 24 (1), 175–181. Reprinted in R.A. Posner and F. Parisi (eds.) *The Coase* Theo*rem.* Economics Approaches to Law Series. 2013. Edward Elger Publishing.
Aivazian, V.A., Callen, J.L., 1983. Core theory and uniformity in accounting: rationalizing the accounting rule maker. J. Account. Public Policy 2 (4), 225–237.
Aivazian, V.A., Callen, J.L., 2003. The core, transaction costs, and the Coase Theorem. Const. Political Econ. 14 (4), 287–299.
Aivazian, V.A., Callen, J.L., Lipnowski, I., 1987. The Coase Theorem and coalitional stability. Economica 54 (216), 517–520. Reprinted in R.A. Posner and F. Parisi (eds.) *The Coase* Theo*rem.* Economics Approaches to Law Series. 2013. Edward Elger Publishing.
Aivazian, V.A., Callen, J.L., McCracken, S., 2009. Experimental tests of core theory and the Coase Theorem: inefficiency and cycling. J. Law Econ. 52 (4), 745–759. Reprinted in R.A. Posner and F. Parisi (eds.) *The Coase* Theo*rem.* Economics Approaches to Law Series. 2013. Edward Elger Publishing.
Aivazian, V.A., Callen, J.L., 2019. The Coase Theorem and the Theory of the Core. In: Marciamo, A., Ramello, G. (Eds.), Encyclopedia of Law and Economics. Springer, pp. 1–5.
Allen, D.W., 2015. The Coase Theorem: coherent, logical, and not disproved. J. Inst. Econ. 11 (2), 379–390.
Ambec, S., Kervinio, Y., 2016. Cooperative decision-making for the provision of a locally undesirable facility. Soc. Choice Welf. 46, 119–155.
Anderlini, L., Felli, L., 2001. Costly bargaining and renegotiation. Econometrica 69 (March), 377–411.
Anderlini, L., Felli, L., 2006. Transaction costs and the robustness of the Coase Theorem. Econ. J. 116 (January), 223–245.
Arrow, K.J., 1979. The Property Rights Doctrine and Demand Revelation under Incomplete Information. In: Boskin, Michael J. (Ed.), Economics and Human Welfare: Essays in Honor of Tibor Scitovsky. Academic Press, New York, pp. 23–29.
Aumann, R.J. (1985) "What is Game Theory Trying to Accomplish", In *Frontiers of Economics*, edited by K.J. Arrow and S. Honkapohja, 5–46.
Aumann, R.J., 1987. Game Theory. In: Eatwell, J., Milgate, M., Newman, P. (Eds.), The New Palgrave, A Dictionary of Economics, Vol 2. Macmillan, London and Basingstoke, pp. 460–482.
Aumann, R.J., Maschler, M., 1964. The Bargaining Set for Cooperative Games. In: Dresher, Melvin, Shapley, Lloyd S., Tucker, Albert W. (Eds.), Advances in Game Theory. Princeton University Press, Princeton, N.J, pp. 443–476.
Bar-Gill, O., Engel, C., 2016. Bargaining in the absence of property rights: an experiment. J. Law Econ. 59, 477–495.
Beal, S., Durieu, J., Solal, P., 2008. Farsighted coalitional stability in TU-games. Math. Soc. Sci. 56 (3), 303–313.
Bernholz, P., 1997. Property rights, contracts, cyclical social preferences and the Coase Theorem: a synthesis. Eur. J. Political Econ. 13, 419–442.
Bittlingmayer, G., 1982. Decreasing average costs and competition. J. Law Econ. 25, 201–229.
Calabresi, G., Melamed, A.D., 1972. Property rules, liability rules, and inalienability: one view of the cathedral. Harv. Law Rev. 85, 1089–1128.
Chipman, J.S., 1998. A Close Look at the Coase Theorem. In: Buchanan, J.M., Monissen, B. (Eds.), The Economists' Vision. *Essays in Modern Economic Perspectives*. Campus Verlag, Frankfurt am Main, pp. 131–162 (1998).
Chwe, M.S., 1994. Farsighted coalitional stability. J. Econ. Theory 63, 299–325.
Coase, R., 1960. The problem of social cost. J. Law Econ. 3, 1–44.
Coase, R., 1981. The Coase Theorem and the Empty Core; A Comment. J. Law Econ. 24, 183–187.
Crettez, B., 2020. The Coase Theorem, the Non-empty Core, and the Legal Neutrality Principle. Rev. Law Econ. 16, 1–16.
d'Arge, R.C., 1973. Coase Theorem symposium: introduction. Nat. Resour. J. 13, 557–560.
Dixit, A.K., Olson, M., 2000. Does voluntary participation undermine the Coase Theorem? J. Public Econ. 76, 309–335.
Dutta, B., Ray, D., Sengupta, K., Vohra, R., 1989. A consistent bargaining set. J. Econ. Theory 49, 93–112.
Ellingsen, T., Paltseva, E., 2016. Confining the Coase Theorem: contracting, ownership and free-riding. Rev. Econ. Stud. 83 (2), 547–586.
Friesen, L., McKenzie, I.A., Nguyen, M.P., 2022. Initially Contestable Property Rights and Coase: Evidence from the Lab. Discussion Paper No. 656. The University of Queensland School of Economics,.
Gangopadhyay, P., 2000. On the Coase Theorem and coalitional stability: the principle of equal concession. Theory Decis. 48 (2), 179–191.
Gonzalez, C., Marciano, A., Solal, P., 2019. The social cost problem, rights, and the (non) empty core. J. Public Econ. Theory 21 (2), 347–365.
Graham, D.A., Jacobson, E., Weintraub, E.R., 1972. Transactions costs and the convergence of a trade "out of equilibrium" adjustment process. Int. Econ. Rev. 13 (1), 123–131.
Guzzini, E., Palestrini, A., 2009. The empty core in the Coase Theorem: a critical assessment. Econ. Bull. 29 (4), 3095–3103.
Hafalir, I., 2007. Efficiency in coalition games with externalities. Games Econ. Behav. 61, 242–258.
Hahn, F., 1971. Equilibrium with transaction costs. Econometrica 39 (3), 417–439.
Harsanyi, J., 1974. An equilibrium-point interpretation of stable sets and a proposed alternative definition. Manag. Sci. 20, 1472–1495.
Hurwicz, L., 1995. What is the Coase Theorem? Jpn. World Econ. 7, 49–74.
Kahan, J.P., Rapoport, A., 1984. Theories of Coalition Formation. Erlbaum, Hillsdale.
Lee, J., Sabourian, H., 2007. Coase Theorem, complexity and transaction costs. J. Econ. Theory 135, 214–235.
Maschler, M., 1978. Playing an N-Person Game: An Experiment. In: Sauermann, H. (Ed.), Coalition-Forming Behavior (Contributions to Experimental Economics). J.C.B. Mohr (Paul Siebeck).
Medema, S.G., 2020. The Coase Theorem at Sixty. J. Econ. Lit. 58 (4), 1045–1128.
Mueller, D.C., 2003. Public Choice III. Cambridge University Press,.
Pirrong, S.C., 1992. An application of Core Theory to the analysis of ocean shipping markets. J. Law Econ. 35, 89–131.
Posner, R.A. (1998). Economic Analysis of the Law, 5th edition. Aspen Law & Business.
Regan, D.H., 1972. The Problem of Social Cost Revisited. J. Law Econ. 15 (2), 427–437.
Robson, A., 2014. Transaction costs can encourage coasean bargaining. Public Choice 160, 539–549.
Scarf, H., 1986. Notes on the Core of a Production Economy. In: Hildebrand, W., Mas-Collel, A. (Eds.), Contributions to Mathematical Economics in Honor of Gerard Debreu. North-Holland, Amsterdam, pp. 401–429.
Shubik, M., 1983. Game Theory in the Social Sciences: Concepts and Solutions, Volume 1. M.I.T. Press, Cambridge, Mass.

[30] This conjecture leads to the notion of consistent bargaining sets. See Dutta et al. (1989).

[31] For examples in the context of corporate finance and accounting, see Aivazian and Callen (1980) and Aivazian and Callen (1983), respectively.

Shubik, M., 1984. A Game Theoretic Approach to Political Economy. M.I.T. Press.
Sjostrom, H., 1989. Collision in Ocean Shipping: A Test of Monopoly and Empty Core Models. J. Political Econ. 97, 1160–1179.
Stigler, G.J., 1966. The Theory of Price, 3rd ed.,. Macmillan, New York.
Techer, K., 2021. Stable agreements through liability rules: a multi-choice game approach to the social cost problem. Math. Soc. Sci. 111 (C), 77–88.
Telser, L., 1994. The usefulness of core theory in economics. J. Econ. Perspect. 8, 151–164.
Telser, L., 2007. The Core Theory in Economics: Problems and Solutions. Routledge.
Zhao, J., 2018a. TU oligopoly games and industrial cooperation. Handb. Game Theory Ind. Organ. Vol. 1 (Ch. 14), 392–422.
Zhao, J., 2018b. A reexamination of the Coase Theorem. J. Mech. Inst. Des. 3 (1), 111–132.