Games and Economic Behavior 144 (2024) 183–202

Contents lists available at ScienceDirect

Games and Economic Behavior

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

Partnerships based on Joint Ownership ☆

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ARTICLE INFO

JEL classification:
D23
L22

Keywords:
Relational contracts
Joint Ownership
Property rights
Renegotiation
Coase Theorem

ABSTRACT

In a unifying framework generalizing established theories we characterize under which conditions Joint Ownership of assets creates the best cooperation incentives in a partnership. We endogenise renegotiation costs and assume that they weakly increase with additional assets. A salient sufficient condition for optimal cooperation incentives among patient partners is if Joint Ownership is a *Strict Coasian Institution* for which transaction costs impede an efficient asset reallocation after a breakdown. In contrast to Halonen (2002) the logic behind our results is that Joint Ownership maximizes the value of the relationship *and* the costs of renegotiating ownership after a broken relationship.

1. Introduction

How should a partnership be set up to provide the best incentives for success and longevity? In particular, who should own which assets and under which circumstances? May joint ownership, i.e. a situation where the use of the asset requires the consent of all owners, be a better recipe for lasting success compared to private ownership where a single party can freely decide over the use of the asset? In this paper, we revisit the problem of allocating asset ownership among business parties to improve incentives for cooperative behavior in long-term relationships. Compared to the pertinent work on the subject, such as Garvey (1995) Halonen (2002) or Baker et al. (2002) our paper offers methodological contributions and novel predictions.

To capture the diverse settings that have been studied in the existing literature, we consider a general strategic environment. We make use of techniques applied and developed within the growing literature on relational contracts to tackle the complexity implied by this general framework. One of the key insights of the economic literature on ownership is that it is not only important to understand parties' incentives and behavior during an intact relationship, but even more when the relationship breaks down. The treatment of this critical role of the breakdown case is the first major feature, distinguishing our paper from the existing literature. Consistent with the standard practice in the relational-contracting literature, we assume that, once cooperation breaks down, trading partners separate, instead of continuing to interact non-cooperatively as for example in Halonen (2002). Besides being a more realistic description of how business parties handle breakdowns in practice, crucially, separation implies optimal punishments in the sense of Abreu et al. (1990). Thereby, the threat of a breakup is a more severe and credible punishment compared to continuation of the relationship on a lower level.

When partnerships break down, one must specify how the available assets are allocated between these parties going forward. Therefore, we allow parties to renegotiate the set of assets after a breakdown of cooperation and before they continue their separate

☆ This article owes a lot to former coauthor Giancarlo Spagnolo, the unpublished working paper Blonski and Spagnolo (2002) as well as to a particularly dedicated referee.

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https://doi.org/10.1016/j.geb.2024.01.007
Received 12 June 2017

Available online 19 January 2024
0899-8256/

ways. In most legal systems lawyers' and judges' fees rise with the number and the size of issues haggled over. In this paper, therefore, we suppose that it is less costly to haggle only over a subset of assets. We call this latter assumption *renegotiation asset monotonicity*.[1] The existing literature imposes fixed, exogenous renegotiation costs, rules renegotiation out entirely or assumes that costs are zero. These assumptions are special cases of our present setup.

We follow the tradition of Hart and Moore (1990) by defining a *jointly owned* asset as an asset that can only be turned productive by consent of all owners. Thus, the more assets are jointly owned, the larger the hassle to renegotiate them after a separation. In turn, these negative prospects of separation deter deviations from cooperative behavior within an ongoing relationship. This is the main reason for why joint ownership improves cooperation in long-term relationships. It is also the key difference to existing models such as Halonen (2002) where the optimality of joint ownership requires a.) that players revert to the stage game Nash equilibrium after a defection rather than choosing optimal punishments as well as a b.) a stage game under which joint ownership minimizes incentives for cooperation. By contrast, our general trading environment also incorporates strategic settings where *Joint Ownership* is optimal in the stage game and remains optimal for patient players such as the one studied in Cai (2003). Hence, our analysis underlines that in general, optimal ownership when discount factors are low, can vary widely and depends on the details of the strategic setting.

More than the previous literature on the subject our paper reemphasizes the critical role of renegotiation or transaction costs in determining the optimal asset allocation. In our model, asset ownership affects not only the strategic setting in a given period, but also the costs of renegotiating it off the equilibrium path. For example the presence of inalienable or toxic assets that are either impossible or too costly to renegotiate after a breakdown of the relationship make sure that a termination of the relationship with jointly owned such assets is particularly painful and thereby maximize the incentives to cooperate and to avoid a breakdown. This is the essence of our Theorem 2 which at the same time closely relates Joint Ownership to the *transaction cost literature* considering institutions as being shaped by transaction costs.

Thus, while *Joint Ownership* increases the costs of a breakdown in cooperation as in Halonen (2002), the different mechanism identified in this paper gives rise to novel implications and predictions. With a numerical example we demonstrate that Halonen's key mechanism that "the worst ownership structure of the one-shot game is good in the repeated setting because it provides the highest punishment, but bad because the gain from deviation is also the highest" does not hold generally, though it does in the specific environment analyzed by her. By contrast, we formulate conditions, for which Joint Ownership maximizes the relationship value and creates the strongest cooperation incentives. The contraposition of the Coase-Theorem states that prohibitively high transaction or renegotiation costs can lead to inefficient outcomes as Coase (1960) himself emphasizes. Based on the observation that a breakdown of a relationship renders subsequent renegotiation costs even more pronounced we show that Joint Ownership maximizes incentives for not terminating the partnership in the first place and cooperate instead if players are sufficiently patient (Theorem 2). We provide another sufficient condition that does not on players' patience. It is called constant required liquidity (Theorem 3) and includes models with perfect monitoring such as the one by Halonen (2002). Moreover Joint Ownership is generally more valuable in environments with higher renegotiation costs (Lemma 2).

To derive further results for less patient players, we examine more specific trading environments. In our introductory numerical example we show that private ownership may be inefficient even for impatient players, e.g. when rent-seeking actions are available that affect productivity within and outside the relationship in different ways, a result akin to Cai (2003). We further reconsider the hidden action problem with a principal and an agent in Baker et al. (2002) adding a third option (Joint Ownership) to the ownership design problem and analyzing the classic "make-or-buy" decision in an environment with optimal punishment and costly renegotiation. We show that Joint Ownership always prevails for high renegotiation costs. But also for low renegotiation costs it dominates Integration, because it stipulates both a more severe punishment as well as stronger short-term incentives to cooperate, as the principal cannot "take the output and run", as she can under Integration. It follows that the relevant question reduces to a "collaborate-or-buy" rather than a "make-or-buy" decision.

The paper's case for Joint Ownership when partners are sufficiently patient and haggling costs are substantive may raise the question why Joint Ownership is not more prominent in practice. As argued by Hansmann (1996) and Cai (2003), in business transactions Joint Ownership is much more common than generally perceived. Future work may use this result as a benchmark to extend the literature and find other effects that may balance or pull in different directions in specific institutional environments, much like Elinor Ostrom (1990) suggested to do for properly managing common pool resources.

The remainder of the paper is organized as follows. The first application in section 2 is a numerical example that states precisely how the paper's main results differ from those of Hart and Moore (1990) as well as from Halonen (2002). Section 3 sets up the static framework that underlies the repeated game. Section 4 describes the repeated game and introduces voluntary side payments. Section 5 defines and characterizes optimal and incentive maximizing ownership. Section 6 generalizes the well known results of Baker et al. (2002) if Joint Ownership is an available design while section 7 relates our study to the existing literature. Section 8 concludes. Only short proofs are in the main text, all remaining proofs are in the appendix.

[1] The critical role for haggling after separation of a relationship is evident in *Brexit* where most observers and pundits agreed that the immense number of issues that had to be haggled over imposed heavy renegotiation costs on both sides. Our present theory and results support the old and un-British idea of an ever closer union in the sense that this is the design to minimize the incentives to separate by maximizing the pain of haggling after a separation. Thereby the present EU provides stronger cooperation incentives compared to more flexible and looser settings where parties keep more private control rights and thereby provide much less base for haggling during a possible separation.

Table 1
Stage game payoffs for Joint Ownership and Private Ownership.

His action	l	m	h	r
private cost	0	6	9	3
output	14	22	26	14
surplus	14	16	**17**	11
Joint Ownership				
outside payoffs (*he*, *she*)	(0,0)	(2,0)	(2,0)	(4,0)
JO payoffs (*he*, *she*)	(**7**,7)	(6,10)	(5,12)	(6,5)
Private Ownership				
outside payoffs (*he*, *she*)	(0,0)	(8,0)	(8,0)	(12,0)
PO payoffs (*he*, *she*)	(7,7)	(**9**,7)	(8,9)	(**10**,1)

2. Numerical example

Our first application illustrates how the mechanism behind the paper's main theorems differ from those in the existing literature on optimal ownership in ongoing relationships such as Halonen (2002). To this purpose, we consider a standard action space in the spirit of Grossman, Hart and Moore and show that by adding a rent-seeking action that can be interpreted as investment in general human capital, Halonen's result that joint ownership is optimal for patient players breaks down, while it prevails in our framework.

Consider two players *he* and *she* and one *asset*. *He* is an active player with actions whereas *she* is passive but crucial as a trading partner and only decides whether to stay in the relationship or not. Suppose, *he* has three possible actions $\{l, m, h\}$ interpreted as low, medium and high investments with costs of 0, 6 and 9, respectively. In a relationship with *her*, *his* actions generate output of 14, 22 and 26, accordingly. High investment h means that *he* aims to produce specifically well for *her*, but this additional effort does not raise output with other trading partners outside this particular relationship. Moreover, outside the relationship, say, with the best alternative trading partner, *he* can realize outside payoffs of 0, 8 and 8 for actions $\{l, m, h\}$ respectively. *Her* outside payoff is normalized to 0. The left upper part of Table 1 on page 3 wraps up the basic setup.

Clearly, high investment h is efficient and the corresponding joint surplus[2] is $\mathbf{17} = 26 - 9$ (bold in Table 1). We now compare just *Joint Ownership* with *Private Ownership*, the latter only in the form of *him* owning the asset.[3] Ex post, players split the output according to Nash bargaining with symmetric bargaining power.

Under Joint Ownership, *he* will choose l which yields *him* payoff $\mathbf{7} = \frac{1}{2} \cdot 14 - 0$ (bold in Table 1) and generates total surplus 14. Choosing m instead would generate a better surplus of 16 but only payoff $6 = 2 + \frac{1}{2} \cdot [22 - 2] - 6$ for *him*.

Suppose, as private owner *he* can put the asset to alternative use. Outside the relationship with *her* there is no incentive to invest more than the medium investment since high investment was assumed to be specific to *her*. Hence, *he* will choose m with payoff equal to the Nash bargaining outcome minus investment cost, i.e. $\mathbf{9} = 8 + \frac{1}{2}[22 - 8] - 6$ (again, bold in Table 1) creating surplus 16.

This initial part of the example replicates the well known story from Hart and Moore (1990) for which Private Ownership raises *his* investment incentive by improving *his* bargaining position. Next, we show that this logic may turn upside down if *he* has an extended action space $\{l, m, h, r\}$ with an additional "rent seeking" action r interpreted as an (asset-specific) investment into general human capital generating *him* private cost 3. This action enhances the value of the asset only outside the relationship, which is bad for the relationship since it is costly. It does not raise output compared to the low action, thereby reducing the joint surplus to 11, while it raises *his* outside payoff to 12 if *he* is the owner of the asset.[4] Since we interpret r as rent seeking or an investment into general human capital, we assume that *his* outside payoff under joint ownership increases to 4, implying that, even if *he* does not own the asset, he can extract some, though not all, of the value of his general human capital investment.

Under Private Ownership *he* as the owner of the asset will now prefer action r yielding *him* a payoff of $\mathbf{10} = 12 + \frac{1}{2}[14 - 12] - 3$ (bold in Table 1). Under Joint Ownership adding this action does not affect his optimal choice and the outcome since as before *he* sticks with *low* investment yielding the higher second best surplus 14.

In the repeated version with joint discount factor δ the relationship value is the difference between the surplus stream within the relationship and the surplus stream outside the relationship. In Halonen's (2002) framework the surplus stream outside the relationship is given by the sum of Nash reversion payoffs or, in other words, the surplus from the perpetual play of the stage game equilibrium. Consider now the stage game with extended action space $\{l, m, h, r\}$. In the logical extension of Halonen's model[5] Private Ownership would generate the larger relationship value $\frac{1}{1-\delta}((26-9)-(14-3)) = \frac{6}{1-\delta}$ as would Joint Ownership, which is $\frac{1}{1-\delta}((26-9)-(14-0)) = \frac{3}{1-\delta}$. Hence, in Halonen's setup Private Ownership is more valuable and thereby it can be supported as an

2 Exogenous and bold numbers are explained in text, all other numbers are calculated similarly.

3 This is the more interesting case for this example since only *he* can take actions. The general theory covers all cases.

4 Cai (2003) already showed that Joint Ownership may yield a higher surplus than Private Ownership even in a static game. In his model this happens once specific and general investments are substitutes rather than complements. The present example builds on Cai's idea but tells a somewhat different story by emphasizing the asset specific action "rent seeking", i.e., for which the asset value rather than human capital varies with ownership.

5 Note that a rent seeking action like this is excluded by assumption in a one-dimensional action space as in Hart and Moore (1990) or Halonen (2002).

Table 2
Surplus and Optimal Ownership in Numerical Example.

action space	our theory $\delta = 0$ $\{l, m, h\}$	our theory $\delta = 0$ $\{l, m, h, r\}$	our theory $\delta \to 1$ $\{l, m, h\}$	our theory $\delta \to 1$ $\{l, m, h, r\}$	Halonen $\{l, m, h, r\}$
JO	14	14	$15 + o(z^0)$	$8 + o(z^0)$	$\underline{\delta} = \frac{2}{5}$
PO	16	11	15	8	$\underline{\delta} = \frac{1}{4}$

equilibrium for a larger range of discount factors compared to Joint Ownership which is her optimality criterion for the dynamic case.[6]

In our formulation, by contrast, the relationship terminates after breakdown and former partners turn to alternative trading partners once cooperation breaks down. Since a jointly owned asset has no value outside the relationship former partners anticipate that ownership rights of the jointly owned asset have to be haggled over. Suppose that it costs $z^0 > 0$ to haggle and to alter ownership to the next best alternative which would be Private Ownership. This implies that in our model the relationship value of Joint Ownership is $\frac{1}{1-\delta}(26-9) - \left[\frac{1}{1-\delta}(12-3) - z^0\right] = \frac{8}{1-\delta} + z^0$ which outperforms the relationship value for private ownership given by $\frac{1}{1-\delta}(26-9) - \left[\frac{1}{1-\delta}(12-3)\right] = \frac{8}{1-\delta}$. Moreover, this shows that the relationship value of an ownership structure increases with haggling cost z^0 that becomes relevant once the partnership breaks down.

Table 2 wraps up the main message of this example. Our theory proposes in contrast to the logical extension of Halonen that the asset should rather be jointly owned if players are sufficiently patient no matter whether a rent seeking action is available or not. According to the theory in this article the entries in the table display the relevant criterion for optimal ownership. For impatient players this is the surplus.[7] For patient players in our theory the surplus is always maximal. Hence, the table entries compare the size of the aggregated incentives which for patient players correspond to the per period value of the relationship.[8] Since patient players can always obtain maximal surplus Halonen picks the lower bound of discount factors $\underline{\delta}$ as her optimality criterion. The expression $o(z^0)$ in the per period surplus of Table 2 converges to 0 for $\delta \to 1$ since the haggling costs z^0 are only relevant in the breakup period. The circles indicate the optimal ownership structure within our, respectively Halonen's frameworks.[9] Though with the surplus-destructive nature of "rent seeking" our current example differs from Cai (2003), it extends Cai's observation that even if players are impatient there are other relevant stage games beyond the Hart and Moore (1990) scenario for which Joint Ownership yields a strictly higher surplus than Private Ownership.

3. Static framework

We begin by describing the stage game environment and in the next section, turn to the repeated game which is our main focus. Consider two risk-neutral players $i = 1, 2$ who decide simultaneously on costly actions $e_i \in E_i$ in a compact action space E_i. Let

$$e = (e_1, e_2) \in E = E_1 \times E_2$$

be an action profile. Our specification includes both cases of observable actions (perfect monitoring) and of non-observable actions (imperfect monitoring). An action e_i might e.g. be a complex high-dimensional plan for conducting business for all contingencies that might be relevant during the stage game.[10] Let (Ω, σ) be a probability space with Ω denoting the set of all possible states of nature with typical element ω and with sigma algebra σ. Actions generate a stochastic joint project payoff $Q(e, \omega) \geq 0$ as well as (potentially stochastic) private costs $C_i(e_i, \omega)$ to player i. The expected joint surplus of the stage game is given by

$$S(e) = \mathbb{E}\left[Q(e, \omega) - C_1(e_1, \omega) - C_2(e_2, \omega)\right]$$

[6] Halonen (2002) already pointed out that allowing renegotiation would alter her conclusions. She provided a corresponding numerical example with exogenous renegotiation cost at the end of her article, but no general results.

[7] In the one-shot version $\delta = 0$ of the model the surplus $14 = 7 + 7$ in the upper row of Table 2, for example, results by adding up the *his* and *her* payoffs from Table 1 for the action l that is optimal for *him* under JO.

[8] For example, in the model with four actions $\{l, m, h, r\}$ the relationship value $8 + o(z^0) = 17 - 9 + o(z^0)$ in the first row is measured by the difference of the per period surplus 17 within and $9 - o(z^0)$ outside the relationship

[9] One of our referees came up with the interesting observation that the required liquidity also differs among the different scenarios. While this does not affect our predictions for patient and impatient players in Table 2 it indeed matters for all intermediate discount factors. Since this highly specific numerical example is designed to point out the differences to the literature we do not analyze intermediate levels of patience here. However, in the next Example 6, we apply our results to intermediate levels of patience as well.

[10] We also allow action spaces to consist of only one element. As in our numerical example in section 2 or in the principal agent setting in section 6 our theory includes cases where one player is not strategic.

where $\mathbb{E}$ denotes the expectation operator with respect to (Ω, σ). Suppose there exists a unique action profile $e^c = \left(e_1^c, e_2^c\right) \in E$ – the *cooperative action profile* – that maximizes the size of the expected joint surplus given by $S^* := S(e^c)$.

3.1. Asset ownership

Let A denote a fixed set of non-human assets. *Ownership structure* or just *ownership* $\alpha = \left(A_1, A_2, A_{12}\right)$ is a partition of A, i.e. the subsets A_i and A_{12} are mutually exclusive and their union is A. The sets A_i are privately owned assets of party i, and A_{12} are jointly owned assets. This implies that all assets are owned either privately or jintly in every feasible ownership structure.

Our interpretation of ownership follows the tradition of Hart and Moore. Ownership of an asset confers control rights and ultimately veto power over the use of the asset. Joint Ownership means that every owner has veto power, i.e. a jointly owned asset can only be used with the consent of all owners. Ownership α is observable and verifiable in court.

The salient cases of ownership are (i) *Joint Ownership* $\alpha^J = (\emptyset, \emptyset, A)$ where $A_{12} = A$, (ii) *Integration* α^I, where one party, say $i = 1$ owns all assets, so that $A_1 = A \neq \emptyset = A_2 = A_{12}$, (iii) *Outsourcing* α^O where both parties own assets, but there are no jointly owned assets so that $A_1 \neq \emptyset$, $A_2 \neq \emptyset = A_{12}$ and (iv) *Mixed Ownership* α^M where there are both jointly and privately owned assets.

A business partnership, such as one among consultants, lawyers or architects will typically feature mostly jointly owned assets such as the brand or firm name, client lists as well as decision rights and claims to the firm's returns. Joint ventures for example will feature both jointly (decision rights, claims to R&D results) as well as individually owned assets such as buildings and machines.

3.2. Disagreement payoffs

Action profile e together with ownership structure α generates stochastic *disagreement payoffs*

$$\left(P_1\left(e_1, A_1, \omega\right), P_2\left(e_2, A_2, \omega\right)\right) \in \mathbb{R}^2,$$

representing players' individual payoffs P_1, P_2 if they decide not to trade with each other. Player i's disagreement payoff $P_i\left(e_i, A_i, \omega\right)$ depends only on his privately owned assets A_i. E.g., if negotiations over a business partnership or a joint venture break down, P_1 and P_2 reflect what each party can get employing its assets in the next-best alternative. Clearly, generally e_i^c is not the optimal action that maximizes P_i outside of the relationship.

3.3. Inside ownership weights

Action profile and ownership together with the state of the world determine the division of the joint payoff inside the relationship, i.e. who receives how much of the joint payoff Q once it is produced. We introduce the notation

$$q(e, \alpha, \omega) = \left(q_1(e, \alpha, \omega), q_2(e, \alpha, \omega)\right) \in \left\{(q_1, q_2) \in \mathbb{R}_+^2 \left| q_1 + q_2 = 1 \right.\right\}.$$

The weights $q = (q_1, q_2)$ specify the default division of the joint output if the two parties cannot agree on any other division of it. This formulation comprises a broad range of different division rules. E.g. if some parts of (e, α, ω) are contractible, q could reflect the contractible division of the joint surplus, such as fixed wages, bonuses based on verifiable outcomes or party's equity shares, reflecting their claims to the relationship's returns. If all components of (e, α, ω) are non-verifiable, weights q could reflect the outcome of the ex-post Nash-bargaining process of the static game. This general weights formulation allows us to compare various salient contributions in the literature as special cases within our theory. In the Grossman-Hart-Moore (GHM) framework, an investing player is essential to realizing the ex-post gains from his investment, implying that both the set of assets and the identities of the players who cooperate determine the resulting surplus (see Hart and Moore, 1990). In that context players can be interpreted as investing in human capital. Since then players can always withhold their contribution to the joint surplus, it is natural to assume that it is split according to the Nash bargaining solution. By contrast, if players invest into physical capital, only the allocation of ownership matters for the size of the surplus. In Baker et al. (2002), under Integration, the principal can realize the gains from the agent's investment without having to ask him for permission which amounts to an outside option $Q(e)$ for the principal. The formulation based on weights $q = (q_1, q_2)$ nests both interpretations. For $q_i(e, \alpha) = \frac{1}{2} + \frac{P_i(e_i, \alpha) - P_{-i}(e_{-i}, \alpha)}{2Q(e)}$, we get the human capital interpretation. If $q_i(\alpha)$ is independent of e, we get the physical-capital interpretation. Indeed, as we allow the joint payoff Q itself to be part of the set of assets, we additionally allow asset ownership to determine what Segal and Whinston (2013) have termed "pure cash rights".

In the dynamic model we allow for voluntary side payments which will generally lead to a surplus division that differs from q. Consistent with the literature we assume that voluntary side payments need to be self-enforcing and can be contingent on any observable (but potentially non-verifiable) information.

Under ownership structure $\alpha = \left(A_1, A_2, A_{12}\right)$, the stage-game payoff for player i is given by

$$q_i(e, \alpha, \omega) Q\left(e, \omega\right) - C_i\left(e_i, \omega\right).$$

For any ownership structure α the *expected payoff* for player i is given by

$$u_i\left(e, \alpha\right) := \mathbb{E}\left[q_i(e, \alpha, \omega) Q\left(e, \omega\right) - C_i\left(e_i, \omega\right)\right].$$

Fig. 1 summarizes the sequence of events in the stage game.

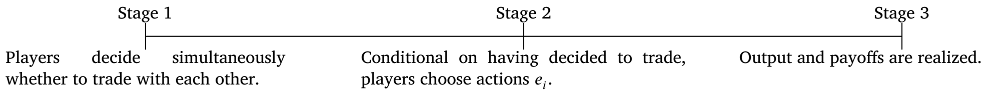

Fig. 1. Sequence of events in the stage game.

3.4. *Assets in limbo*

If the relationship breaks down joint ownership assets A_{12} are in a limbo state until disaffected parties are able to agree on their further use. Sometimes it might be most efficient in the long run if party i owns these assets privately outside the relationship and buys out party $-i$. In other cases it might be more efficient to sell A_{12} or a part of it to a third outside party and share the proceeds in some way. But often assets stay in a limbo state for a long time or forever if both parties are not willing to give up control for a price that either the ex-partner or a third party is willing to pay. We further reflect on this in subsection 3.8.

3.5. *Relationship design problem*

Any ownership structure α defines a stage game $\Gamma(\alpha)$ in which, at a first stage, players decide whether or not to trade with each other, and then at a second stage they play a simultaneous-move game with payoffs $u_i(e,\alpha)$. In general, players that maximize $u_i(e,\alpha)$ do not maximize the joint surplus $S(e)$. We consider static games $\Gamma(\alpha)$ that are characterized by (i) a unique action e^c that maximizes $S(e)$ for any ownership structure $\alpha = (A_1, A_2, A_{12})$ and (ii) a unique (pure strategy) Nash equilibrium, called *holdup equilibrium* $e^d(\alpha) = (e_1^d(\alpha), e_2^d(\alpha))$ with $e_i^d(\alpha) \neq e_i^c$ for $i = 1,2$ and any $\alpha = (A_1, A_2, A_{12})$.

We define ownership structure $\hat{\alpha}$ as *short-term efficient* if $\hat{a} \in \operatorname{argmax}_\alpha S(e^d(\alpha))$, i.e. it maximizes the joint holdup equilibrium surplus.

3.6. *Outside payoffs*

Instead of playing the simultaneous-move game described above, at the beginning of the stage game, players can also opt not to trade with each other at all. In that case, each player i obtains an *outside payoff*

$$u_i^0(A_i) = \mathbb{E}\left[P_i\left(e_i^0(A_i), A_i, \omega\right) - C_i(e_i^0(A_i), \omega)\right],$$

where

$$e_i^0(A_i) \in \underset{e_i}{\operatorname{argmax}}\, \mathbb{E}\left[P_i\left(e_i, A_i, \omega\right) - C_i(e_i, \omega)\right].$$

is the corresponding optimal action. Note that as $P_i\left(e_i, A_i, \omega\right)$ depends only on privately owned assets A_i of ownership structure $\alpha = (A_1, A_2, A_{12})$, so does $u_i^0(A_i)$. Define

$$U^0(\alpha) = u_1^0(A_1) + u_2^0(A_2) \tag{1}$$

as aggregated outside payoffs. These payoffs will play the role of optimal punishment payoffs in the repeated game.

3.7. *Outside payoff asset monotonicity*

Our interpretation of a relationship that has broken down is that parties become unable to trade with each other and cannot use jointly owned assets for productive purposes. This is reflected by the fact that joint assets only create favorable/productive incentives in the stage game, but not if players choose their outside payoffs. Therefore, a natural assumption is that for ownership structure $\alpha = (A_1, A_2, A_{12})$, disagreement payoffs P_i satisfy *outside payoff asset monotonicity* defined by

$$u_i^0(A_i) \leq u_i^0(A_i') \text{ for } A_i \subseteq A_i'. \tag{2}$$

Hence, privately owning more assets never reduces the outside payoff since there is always the option not to use them.[11] Clearly, players will have an incentive to renegotiate asset ownership if it does not maximize outside payoffs already.

[11] This is reminiscent of *free disposal* in general equilibrium theory. Once we discuss renegotiation there will be another property called *renegotiation asset monotonicity*.

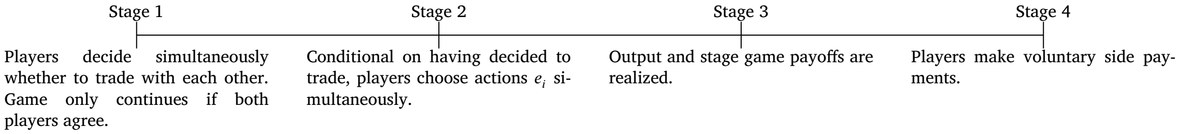

Fig. 2. Sequence of events in a representative period t.

3.8. *Inalienable or toxic assets and inefficient breakups*

We call ownership $\tilde{\alpha}$ *efficient outside the relationship*, if no other ownership α yields higher aggregated outside payoffs or

$$\tilde{\alpha} \in \underset{\alpha}{\operatorname{argmax}}\, U^0(\alpha). \tag{3}$$

A scenario where the relationship breaks up and parties are unable to agree ex post to an efficient ownership outside the relationship will be called an *inefficient* or a *bad breakup*. A reason for this can be *inalienable* or a *toxic* assets. The world is full of inalienable assets as inalienability may have numerous reasons. First, some physical or tangible assets may be simply illegal, impossible or at least prohibitively expensive to be traded or to be transported. Second, many intangible assets are inalienable because they cannot be contracted on such as trust, reputation, a common history, promises, a family name, a real or perceived secure environment, a common secret or some complementary knowledge. It is hard to find a functioning real world relationship that does not contain some inalienable assets. Under Joint Ownership inalienability necessarily leads to a bad breakup if the respective asset is more valuable inside the relationship than outside.

A *toxic* asset is even worse outside a relationship. We define it as an asset $\xi \in A$ for which (i) no party is willing to give up control over it for a reasonable price neither to the ex-partner nor to a third party and (ii) it is valuable in the sense that both parties $i \in \{1,2\}$ strictly prefer to own it outside the relationship, i.e. $u_i^0(A_i \cup \xi) > u_i^0(A_i)$ for all $A_i \subset A$, or alternatively, strictly hate it if the ex-partner owns it, or both. Toxic assets have the property that outside the relationship they should never be jointly owned, because they will cause trouble, stay in limbo and they prohibit efficient ownership outside the relationship and thereby every breakup with a jointly owned toxic asset ends up badly. Another reason for a bad end of a relationship is costly renegotiation. We come back to this in section 4.

4. The repeated game

Suppose now that the stage game $\Gamma(\alpha)$ is repeated in each of infinitely many periods indexed by $t = 1, 2, \ldots$. Thus, in this section, we add t-indices to all variables except for ownership α which remains constant over the course of the relationship and drop them again once they are recognized to be stationary. The repeated interaction may allow players to sustain cooperative behavior in a given period t by threatening to sanction any deviation from specified behavior in future periods.

4.1. *Side payments*

We add to the stage game $\Gamma(\alpha)$ the possibility for players to exchange side payments at the end of each period. In particular, denote the net payments made at the end of period t by $\beta_t = (\beta_{t1}, \beta_{t2})$ where $\beta_{ti} \geq 0$ if player i pays and $\beta_{ti} \leq 0$ if player i gets payed. Side payments $\beta_t = (\beta_{t1}, \beta_{t2})$ are feasible if $\beta_{t1} + \beta_{t2} = 0$. These can be conditioned on all variables that are jointly observed by both players up to t. However, in contrast to the payments specified by $q(\cdot)$, the payments in β_t are voluntary. Please note that without loss of generality, we can disregard money burning.[12] Additionally we allow players to exchange up-front side payments in the first period of the repeated game denoted by $\beta_0 = (\beta_{01}, \beta_{02})$. These can be interpreted as entry fees or buy-in-payments.[13]

In the repeated game, β_0 is used to shift (quasi-)rents between the two players, while β_t for $t \geq 1$ will be used to administer players' incentives to take particular actions within period t. Therefore, the up-front side payments β_0 do not depend on the history of play while side payments β_t for $t \geq 1$ will be functions of all jointly observed variables up to the point when they are made. Since we allow for imperfect public monitoring the actions from earlier periods may or may not be among the jointly observed variables. Fig. 2 illustrates the timing of events in the stage game with side payments.

The expected joint surplus in period t is given by

$$S_t(e_t) = \mathbb{E}\left[Q\left(e_t, \omega\right) - C_1\left(e_{t1}, \omega\right) - C_2\left(e_{t2}, \omega\right)\right]. \tag{4}$$

[12] While it is known that the possibility of money burning, i.e. $\beta_{t1} + \beta_{t2} > 0$ may generally affect the payoff set of repeated games with side payments under imperfect monitoring Goldlücke and Kranz (2012) show that money burning does not enlarge the equilibrium payoff set of the repeated game if the stage game has a Nash equilibrium that gives each player her min-max payoff. Since in our framework the decision to assume that every player has the option to terminate the relationship without having to establish such a Nash equilibrium we do not have to worry about money burning from here and remove it from our notation without loss of generality.

[13] Goldlücke and Kranz (2012) assume that transfers can be performed at the beginning *and* at the end of each stage. To save on notation we omit the transfer payments at the beginning of each stage.

Since the side payments are voluntary they have to be made self-enforcing by an appropriate choice of continuation play. We assume that if a player fails to make an appointed payment, both players revert to playing the optimal punishment profile under which mutual trade ceases and both players turn to their optimal out-of-relationship actions $e_i^0(A_i)$ forever thereafter.[14]

4.2. Renegotiation asset monotonicity

In our setting, if renegotiation is not feasible then outside payoff asset monotonicity makes sure that Joint Ownership minimizes the sum of outside payoffs $U^0(\alpha)$ since it minimizes the set of assets owned privately. By contrast, if players are allowed to renegotiate ownership, they will choose an ownership structure that maximizes the continuation payoff after the break-up, $U^0(\alpha)$.[15] In this paper, we take the view that total renegotiation costs depend on the difference between ownership *from* and ownership *to* which players will negotiate. Intuitively, a renegotiation of ownership that involves reassigning the control rights over only a few assets should generally entail smaller costs than a more complex renegotiation which requires the reallocation of many assets.

Let $RA(\alpha, \alpha') \subseteq A$ denote the *Renegotiation Assets*, i.e. the set of assets that change ownership between the two ownership structures α and α'. We denote by $z^0(RA)$ the (administrative, psychological, and haggling) costs of renegotiating ownership for all assets in the set RA. We now say that renegotiation costs $z^0(RA)$ satisfy *renegotiation asset monotonicity* if

$$z^0(RA) \leq z^0(RA') \text{ for } RA \subseteq RA'. \tag{5}$$

If a relationship breaks down, players have an incentive to renegotiate to an ownership that yields the highest joint continuation payoff. If a relationship with ownership structure α breaks down, players will renegotiate to an ownership structure

$$\alpha^R(\alpha) \in \underset{\widetilde{\alpha}}{\operatorname{argmax}}\ U^0(\widetilde{\alpha}) - \frac{1-\delta}{\delta} z^0(\alpha, \widetilde{\alpha}) \tag{6}$$

that yields the highest joint continuation payoff, where $z^0(\alpha, \widetilde{\alpha})$ is a short notation for $z^0(RA(\alpha, \widetilde{\alpha}))$, i.e. the renegotiation cost from α to $\widetilde{\alpha}$. Let

$$\bar{U}^0(\alpha) := U^0(\alpha^R(\alpha)) - \frac{1-\delta}{\delta} z^0(\alpha, \alpha^R(\alpha)) \tag{7}$$

denote the optimal joint per period continuation payoff of a relationship with ownership structure α that breaks down where α^R denotes the *resulting* ownership structure after haggling over the assets. Note that in this definition renegotiation costs $z^0(\cdot)$ are multiplied by $\frac{1-\delta}{\delta}$ since they are only payed once in period t while ex-post payoffs $U^0(\alpha^R(\alpha))$ start in period $t+1$ and are realized indefinitely. Thus, even though players are free to reassign asset ownership after a relationship breaks down, the current ownership structure does affect the costs of renegotiation and therefore also the optimal reallocation of assets. Renegotiation asset monotonicity implies that Joint Ownership minimizes players' joint continuation payoff after breakdown for any action e. If renegotiation asset monotonicity is strict Joint Ownership is even the unique ownership structure with this property. Clearly, for sufficiently high renegotiation cost z^0 parties would prefer to abide with the current ownership structure, i.e. $\alpha^R(\alpha) = \alpha$.

Lemma 1. *$\bar{U}^0(\alpha)$ is minimized by Joint Ownership α^J.* □

Lemma 1 holds irrespective of the size of the renegotiation costs including the case of no renegotiation corresponding to infinite renegotiation costs considered by Halonen (2002). Since outside of the relationship jointly owned assets become useless, Joint Ownership always minimizes the continuation payoff as it entails the highest renegotiation costs among all initial ownership structures.

4.3. Joint Ownership as a Strict Coasian Institution

As an example consider the case with only one asset a with the property that outside the relationship it is only strictly valuable if owned privately by some party but which turns useless if owned jointly, i.e. $u_i^0(a) > 0$ for $i = 1, 2$ and $U^0(\alpha^R(\emptyset, \emptyset, a)) = 0$. A good example for this is a bequested house that could be used or sold if owned privately but not if it is owned jointly and the joint owners are unable to agree on its use or on selling it and hence it remains in a limbo state. We know already from the last paragraph of section 3 that this kind of inefficiency after a breakup is unavoidable[16] if asset a is inalienable or toxic. However, even without an inalienable or toxic asset Joint Ownership may uniquely minimize the permanent payoff after a breakup and be inefficient because renegotiation costs are simply too high or in this example $z^0 > \frac{\delta}{1-\delta}(U^0(\alpha) - U^0(\alpha^J))$. The contraposition of this is the basic idea behind the Coase Theorem which in our wording and notation states that for sufficiently low renegotiation costs an ex-post outcome $U^0(\alpha^R(\alpha))$ is efficient, see Coase (1960). Coase and many of his followers consider transaction costs as the main driving economic force behind many institutions. This motivates the following definition.

[14] As emphasized in the previous section, such behavior constitutes an optimal punishment profile as it minmaxes the respective deviator.

[15] Recall that ownership is contractible. Hence, players can always realize the gains from renegotiation by an appropriate contractual agreement.

[16] Unavoidability refers to the endgame after the breakup of a relationship. Of course the bad breakup is avoidable by staying within the partnership, which is very much why we care about it in the first place.

Definition 1. We call ownership structure $\tilde{\alpha}$ a *Strict Coasian Institution* if it satisfies

$$U^0((\alpha^R(\alpha)) > U^0((\alpha^R(\tilde{\alpha})). \tag{8}$$

for any ownership structure $\alpha \neq \tilde{\alpha}$.

Strictness in the definition refers to the strict inequality in (8). Hence, a Strict Coasian ownership structure is the unique ownership structure with this property. We postulate here that broken relationships make this destructive force of transaction costs in the Coasian sense particularly prevalent.

5. Optimal and incentive maximizing ownership

In this section, we study the optimal design of a relationship. We look for an optimal ownership structure which (i) maximizes the joint surplus and (ii) among those ownership structures maximizes the incentives to adhering to cooperative behavior.

Let

$$\varphi_t \subset \left\{e_t, q_t, Q_t, P_{1t}, P_{2t}, \beta_t\right\}$$

denote the set of variables jointly observed in period t and let

$$h_t = (\beta_0, \varphi_1, \varphi_2, ..., \varphi_{t-1})$$

denote the history of jointly observed variables up to the beginning of date t. By Φ we denote the set of possible realizations of φ_t. Note that this general formulation nests both cases of perfect, as well as imperfect monitoring.

The set of publicly observed variables φ_t is always a strict subset of all the variables $e_t, q_t, Q_t, P_{1t}, P_{2t}, \beta_t$. For example among Q_t, P_{1t}, P_{2t} either Q_t may be observed publicly if the relationship holds and output Q_t is realized. Or, if the relationship breaks down a subset of P_{1t}, P_{2t} may be observed, but Q_t, P_{1t}, P_{2t} are never observed together.

5.1. Equilibrium concept

We study perfect public equilibria (PPE) of the repeated game. In a PPE, players condition their strategies only on public histories as we defined them here, and, after any public history, their strategies must constitute a Nash equilibrium.[17]

5.2. The value of the relationship

Let

$$V(e_t, \alpha) = S_t(e_t) - \bar{U}^0(\alpha) \tag{9}$$

denote the value of a relationship for action profile e_t. Since e^c is salient in yielding the highest surplus S^* call

$$V(\alpha) =: S^* - \bar{U}^0(\alpha) \tag{10}$$

simply the *relationship value* of α. The relationship value reflects the stage game net-productivity of the relationship relative to what the players could achieve by breaking up the relationship and turning to the best alternative outside the relationship.

Lemma 2. *Joint Ownership α^J maximizes the relationship value $V(\alpha)$.* □

Proof. This is a trivial consequence of Lemma 1. ■

5.3. Stationary strategy profiles

In this paragraph, we apply a well known result from the literature on relational incentive contracts that without loss of generality, we can restrict attention to stationary strategies (see Levin (2003) and Goldlücke and Kranz (2012)). Under a stationary strategy profile the same action profile and the same side payments are played forever on the equilibrium path. An equilibrium with a stationary strategy profile is called an *optimal stationary equilibrium* if there is no other stationary equilibrium that implements a higher surplus. Accordingly, an ownership α is *optimal* if it is part of an optimal stationary equilibrium. The structure of the repeated games we analyze is a specification of those formulated and analyzed by Goldlücke and Kranz (2012). They have shown that all

[17] Restricting attention to public strategies is without loss of generality. The agent has private information about the effort profile, but since this private information is one-sided, the outcome of a sequential equilibrium in which players use private strategies is also the outcome of a PPE. See p. 330 in Mailath and Samuelson (2006).

perfect public equilibrium payoffs can be implemented by stationary equilibria that only differ in their up-front payments.[18] This result allows us to focus on ownership structures keeping in mind that many payoff equivalent side payment paths may support the relationship design, among which is the stationary equilibrium. Further, by this result we can simplify, dropping the t-indices in the remainder of the analysis to save on notation. More specifically, if we talk about a side payment profile β we mean $\beta = ((\beta_{01}, \beta_{02}), (\beta_{11}, \beta_{12}), \ldots)$ with up-front payments (β_{01}, β_{02}) in period 1 and stationary side payments (β_{11}, β_{12}) at the end of each period, starting with period 1. If we talk about a side payment without a time index we mean stationary side payments $(\beta_{1t}, \beta_{2t}) = (\beta_1, \beta_2)$ for $t = 1, 2, \ldots$ A stationary side payment $\beta_i : \Phi \to \mathbb{R}$ is a stationary function that depends on the stochastic realization of the jointly observed variables. In particular, this means that the expected side payment $\mathbb{E}(\beta_i)$ is stationary. We now turn to the stationary action profiles that players can implement using such strategies.

5.4. Incentive compatibility

We start with players' incentives to pick a particular action, given some side payment profile β. Levin (2003) has shown that variations in continuation play — the standard tool in the theory of repeated games to provide incentives — can be substituted by appropriate side payments within appropriate boundaries. In particular, a side payment profile β that implements stationary action profile $e = (e_1, e_2) \in E$ as a perfect public equilibrium must satisfy the property that no player has a strict incentive to deviate from the stationary action, i.e.

$$u_i(e, \alpha) - \mathbb{E}(\beta_i | e) \geq u_i\left(e_i', e_{-i}, \alpha\right) - \mathbb{E}(\beta_i | e_i', e_{-i}), \text{ for } i \in \{1, 2\} \text{ and } \forall e_i' \in E_i \tag{11}$$

5.5. Required liquidity

Player i is only willing to make a given side payment $\beta_i(\cdot)$ if it does not exceed the difference between the continuation value $\frac{\delta[u_i(e,\alpha) - \mathbb{E}(\beta_i)]}{1-\delta}$ of keeping the relationship and the continuation value $\frac{\delta u_i^0(\alpha)}{1-\delta}$ from breaking it up. Let $\bar{\beta}_i(e, \alpha) \in \mathbb{R}$ for any stationary equilibrium action profile e denote the maximal side payment in the support of $\beta_i(\cdot)$ that player i may have to pay over all possible outcomes of the history of play. Then, stationary action profile e together with side payment profile β can be implemented as a perfect public equilibrium of the repeated game if and only if (11) holds together with

$$\bar{\beta}_i(e, \alpha) \leq \frac{\delta}{1-\delta}\left[u_i(e, \alpha) - \mathbb{E}\left[\beta_i(e, \alpha)\right] - u_i^0(\alpha)\right], \text{ for } i \in \{1, 2\}. \tag{12}$$

Condition (12) reflects perfection of the side payments. Players must be willing to make any payment on and off the equilibrium path. Levin (2003) has shown that generally there exists a continuum of side payment profiles supporting the same stationary action profile differing by redistribution of the surplus without changing the incentives. This observation leads to a natural boundary with respect to the size of the required transfers. Define

$$\Delta(e, \alpha) := \inf_{\beta}\left[\bar{\beta}_1(e, \alpha) + \bar{\beta}_2(e, \alpha)\right] \tag{13}$$

as the lower boundary on the sum of both players' biggest side payments among all those side payment profiles β that satisfy the equilibrium non-deviation conditions (11) and (12). This expression measures how much short-term transfer payment is at least necessary to implement a certain stationary action profile e under ownership α. Similar to $V(\alpha)$ defined in (10) we use the notation $\Delta(\alpha) =: \Delta(e^c, \alpha)$ for the efficient profile e^c which is our main focus. Following Goldlücke and Kranz (2012), we call $\Delta(\alpha)$ the *required liquidity* necessary to implement cooperation under ownership structure α.

5.6. Constant required liquidity

For a relevant subclass of cases the required liquidity $\Delta(\alpha) \equiv \Delta$ does not depend on ownership α. For example, under perfect monitoring as in Halonen (2002) the required liquidity simplifies to

$$\Delta = u_1(e_1^b(e_2^c), e_2^c) + u_2(e_1^c, e_2^b(e_1^c)) - S^* \tag{14}$$

if $u_i(e, \alpha) = u_i(e)$ does not depend on α. This expression adds up the side payments to players not playing their most preferred action in the stage game and does not depend on ownership α as long as the short term selfish but inefficient best responses to the other player's cooperative action $e_i^b(e_{-i}^c, \alpha) = e_i^b(e_{-i}^c)$ do not depend on ownership.

5.7. Aggregated incentives

Players' short-term incentives to deviate from the cooperative profile e^c under ownership α are quantified by the required liquidity $\Delta(\alpha)$. In particular, the required liquidity of an action profile e is 0 if and only if it is a Nash equilibrium of the stage game. The

[18] Levin (2003) needs court enforced fixed transfers to show that public perfect equilibrium payoffs can be implemented by stationary equilibria. In the proof of Goldlücke and Kranz (2012) the up-front payments take this role to distribute surplus among players. It is noteworthy that the Goldlücke-Kranz result generalizes Levin in various respects, in particular, court enforcement is not necessary since the Goldlücke-Kranz up-front payments are self enforcing.

attainable surplus depends on players' individual incentives to invest. In turn, the relationship design affects these incentives in two different ways. First, it changes the default allocation of surplus and thereby players' incentives in the stage game, i.e. the hold-up problem. We label this the *static incentive*. Players' static incentives to adhere to the cooperative profile e under ownership α are given by the negative of the required liquidity $-\Delta(\alpha)$. Second, repeated interaction allows players to distribute the surplus in ways that are not feasible in a one-shot interaction. In a relationship players can punish defective behavior and/or reward cooperative behavior. Credibility of such actions is supported by players' stakes in the value of the relationship $V(\alpha)$. As stated in the introduction in this paper we are interested in ownership that maximizes the incentive to cooperate. An optimal relationship design should use these two channels in the most efficient way to facilitate efficient trade between the two players. Obviously, the relative weights of these two channels should depend on players' patience. If players are short-sighted or $\delta = 0$ only the static channel is relevant while for infinitely patient players with $\delta = 1$ only the relational channel matters. For cooperation to be sustainable, the required liquidity must be no larger than the discounted expected value of the deviation, which is the maximum loss from the ensuing punishment.

We measure the overall strength of the incentives to cooperate in the relationship by the aggregate incentives, defined as the weighted difference between the relationship value and the required liquidity, i.e. the aggregate deviation incentive in the most parsimonious side payment scheme. We call this weighted sum

$$\delta V(\alpha) - (1-\delta)\Delta(\alpha) \tag{15}$$

the *aggregated relational incentive* since this expression reflects the sum of the incentives to adhere to the prescribed action profile e under ownership structure α, given discount factor δ. Note that for stationary side payments and actions the expression $\frac{\delta V(\alpha)}{1-\delta} - \Delta(\alpha)$ is the sum of the incentives over both players to stick to action profile e in any period where $\frac{\delta V(\alpha)}{1-\delta}$ represents what is at stake if anyone deviates, i.e. the discounted future relationship value from tomorrow on while $-\Delta(\alpha)$ is the sum of the maximal deviation incentives in the least favorable state of nature.

5.8. Dynamic enforcement constraint

The following lemma emphasizes the salient role of the aggregated relational incentive for the implementability of an action profile e under ownership structure α.

Lemma 3. *For any ownership structure α there exists a stationary equilibrium side payment profile β satisfying incentive constraints* (11) *and* (12) *and enforcing full cooperation if and only if*

$$\delta V(\alpha) - (1-\delta)\Delta(\alpha) \geq 0. \quad \square \tag{16}$$

Following Levin (2003), we call condition (16) the *dynamic enforcement constraint*. It states that under some ownership structure α, action profile e^c can be implemented, i.e. there exists some self enforcing stationary payment scheme β if and only if the required liquidity is not greater than the remaining value of the relationship, i.e. $\Delta(\alpha) \leq \frac{\delta V(\alpha)}{1-\delta}$. Unless stated otherwise explicitly from here we restrict attention to cases where players are sufficiently patient such that there exists an ownership structure ownership structure α that satisfies the dynamic enforcement constraint $\delta V(\alpha) - (1-\delta)\Delta(\alpha) \geq 0$ for the efficient[19] action profile e^c. Any such ownership structure is called *optimal*. Mathematically the latter assumption translates into

$$\delta \geq \min_{\alpha} \frac{\Delta(\alpha)}{\Delta(\alpha) + V(\alpha)}. \tag{17}$$

5.9. Optimal and incentive maximizing ownership

Assumption (17) makes sure that surplus S^* can be implemented by some ownership structure. However, this may well not be unique. To the contrary the dynamic enforcement constraint implies that the more patient players are, the more ownership structures fall into this category. Whenever there is more than one ownership structure that maximizes the joint surplus, our following selection criterion picks among those an ownership that provides maximum aggregate incentives not to deviate from the action that implements the maximum joint surplus.

Now we turn to the main questions of this article stated right at the first paragraph of the introduction. A more precise reformulation within this framework is: Which ownership structure is efficient *and* provides the maximal aggregated incentives not to deviate from the efficient mode of behavior? This leading question thereby motivates the following definition for *optimal and incentive maximizing* ownership for a relationship.

Definition 2. Ownership α^* is *optimal and incentive maximizing* if and only if

(i) α^* is optimal.

[19] Note that this assumption does not reduce generality in the sense that in all cases where players are less patient the role of the first best action profile e^c is just taken by another action profile e being less efficient, i.e. generating a lower surplus $S(e) < S^*$. The logic of all subsequent reasoning is valid for any action profile to be implemented.

(ii) $\delta V(\alpha^*) - (1-\delta)\Delta(\alpha^*) \geq \delta V(\alpha') - (1-\delta)\Delta(\alpha')$ for all optimal ownership structures α'. i.e. it maximizes the aggregated incentives $\delta V(e,\alpha) - (1-\delta)\Delta(e,\alpha)$ among the optimal ownership structures. □

In general the optimal and incentive maximizing ownership α^* depends not only on patience δ but also on the relationship value V and the required liquidity Δ. Thereby it generally differs across different strategic environments and depends on the details of the model specification. Nevertheless, we have some general results. The following theorem characterizes optimal and incentive maximizing ownership.

Theorem 1. *The optimal and incentive maximizing ownership structure α^* maximizes*

$$z^0(\alpha, \alpha^R(\alpha)) - \Delta(\alpha) - \frac{\delta}{1-\delta} U^0(\alpha^R(\alpha)) \tag{18}$$

among all optimal ownership structures α, i.e. which satisfy the dynamic enforcement constraint $\delta V(\alpha) - (1-\delta)\Delta(\alpha) \geq 0$. □

Obviously the theorem is a rearrangement of Definition 2 and reflects the tension between the short run incentives $z^0(\alpha, \alpha^R(\alpha)) - \Delta(\alpha)$ and the long run incentive $\frac{\delta}{1-\delta} U^0(\alpha^R(\alpha))$. However, we call it a *theorem* as it is the basis for everything that follows and unifies seemingly different but salient contributions of the literature and sets the stage for numerous more specific, yet more interesting cases.

5.10. Joint Ownership

Under which conditions Joint Ownership is optimal and incentive maximizing? The following Theorem 2 relates all cases where renegotiation costs impede the validity of the Coase theorem to Joint Ownership while Theorem 3 refers to constant required liquidity. Both theorems provide sufficient conditions.

Theorem 2. *If Joint Ownership is a Strict Coasian Institution as in Definition 1 then for sufficiently patient players Joint Ownership is uniquely optimal and incentive maximizing.* □

As patient players concentrate on the long term consequences Joint Ownership uniquely stands out in performing particularly bad after a failed relationship if it is a Strict Coasian Institution. The logic of the proof is that this conversely creates uniquely strong incentives to keep the partnership intact and productive.

Another sufficient condition for Joint Ownership to be optimal and incentive maximizing refers to constant required liquidity or constant deviation incentives in perfect monitoring as stated in (14). Recall that this contains the perfect monitoring case and the model of Halonen (2002).

Theorem 3. *For constant required liquidity Joint Ownership is optimal and incentive maximizing among all optimal ownership structures α. This is valid irrespective of players' patience within the range of discount factors where the dynamic enforcement constraint (17) is satisfied.* □

Proof. The statement follows from Lemma 2 together with $V(\alpha^J) > V(\alpha) \Leftrightarrow \delta V(\alpha^J) - (1-\delta)\Delta > \delta V(\alpha) - (1-\delta)\Delta$. ■

Lemmas 1 and 2 together with Theorems 2 and 3 reflect the advantage of Joint Ownership over other ownership structures under various conditions including all those conditions where the Coase Theorem does not hold because of prohibitively high renegotiation costs or the required liquidity does not depend on ownership. Further, Joint Ownership not only maximizes the relationship value but also the incentives to cooperate if the relationship value strictly differs. Thus, we should expect Joint Ownership to be generally the more beneficial the greater the renegotiation costs. What do we mean by "increasing renegotiation costs"? To make this more precise we define renegotiation costs z^0 to be *bigger* than $\tilde{z}^0$ if and only if

$$z^0(RA) \geq \tilde{z}^0(RA) \qquad \forall RA \subset A. \tag{19}$$

This allows us to compare environments in which the same set of assets is renegotiated at different costs but which are similar otherwise. The next result implies that the range of discount factors for which Joint Ownership supports cooperative behavior increases for increasing renegotiation costs.

Theorem 4. *For any given set RA of renegotiation assets the lower bound on discount factors $\underline{\delta}(\alpha) := \frac{\Delta(\alpha)}{\Delta(\alpha)+V(\alpha)}$ for which action profile e can be implemented under ownership α (including Joint Ownership α^J) decreases for increasing renegotiation costs.* □

Note that the Theorem 4 holds for any action profile e to be implemented, in particular e^c, the efficient one. To translate Theorem 4 into reality notions such as *haggling, renegotiation or transaction costs* or the *range of discount factors* should be interpreted in a measurable way. For example, changes in haggling costs over assets may originate in a more or less corrupt legal system.[20] Note that the range of discount factors supporting cooperation was the criterion on which Halonen's (2002) contribution was based. Theorem 4 refers to the range of discount factors supporting cooperative behavior in a real world population as this has been explored thoroughly by psychologists and been quantified under the term *control of delayed gratification*.[21]

5.11. Further special cases

Independently of Joint Ownership Theorem 1 has further immediate implications for very patient players or for settings with very low or very high renegotiation costs. In two of the following three cases players always renegotiate and the continuation value after renegotiation does not depend on initial ownership, i.e. $U^0 := U^0(\alpha^R(\alpha)) = U^0(\alpha^R(\alpha'))$ for all optimal α, α'. In these cases we denote by $z^0(\alpha)$ the renegotiation cost from α to an ex-post ownership structure resulting in continuation value U^0. This is the case if either players are sufficiently patient (Corollary 1) or renegotiation costs are sufficiently low (Corollary 3). If conversely renegotiation costs are sufficiently high (Corollary 2) parties never renegotiate and the respective costs thereby disappear from the optimality condition.

Corollary 1. *If the discount factor is large enough, the optimal* and *incentive maximizing ownership structure* α^* *maximizes* $z^0(\alpha) - \Delta(\alpha)$. □

Corollary 2. *If parties cannot renegotiate or* z^0 *is always too high, the optimal* and *incentive maximizing ownership structure* α^* *minimizes*

$$\Delta(\alpha) + \frac{\delta}{1-\delta} U^0(\alpha)$$

among all optimal ownership structures α*, i.e. which satisfy* $\delta V(\alpha) - (1-\delta)\Delta(\alpha) \geq 0$. □

Proof. This is a trivial consequence of Theorem 1. ■

Corollary 3. *For sufficiently low renegotiation costs* z^0 *the optimal* and *incentive maximizing ownership structure* α^* *minimizes the required liquidity* $\Delta(\alpha^*)$. □

Proof. When renegotiation costs are sufficiently low, optimal ownership structure depends only required liquidity because the relationship value is constant. The claim is then a trivial consequence of Theorem 1 and the proof of Corollary 1 to be found in the appendix. ■

5.12. Impatient players

This subsection relates the current theory to the static literature where players only play a one-shot version of the game such as in Hart and Moore (1990). Clearly, our model yields those results for sufficiently low discount factors. For impatient players we drop assumption (17) which made sure that cooperation can be achieved under some ownership structure. Sufficiently impatient players cannot cooperate. Hence in this section instead of talking about optimal ownership we talk about surplus maximizing ownership. Which ownership should impatient players agree on?

Proposition 1. *For sufficiently low discount factor* δ *any short-term efficient ownership structure* $\hat{\alpha}$ *maximizes the surplus and the incentives.* □

The intuition behind this result is straightforward. If δ is small enough, the dynamic enforcement constraint is satisfied only for equilibria of the stage game. In our numerical example in section 2 we show that the surplus maximizing ownership even for small δ may be Joint Ownership.

6. Relationship design with moral hazard

In this section, we study optimal ownership within an extended version of Baker et al. (2002) (henceforth BGM). BGM study the optimal relationship design with respect to the "make-or-buy" decision, i.e. they compare Integration with Outsourcing. In particular, we examine a hidden-action problem involving a principal and an agent. Yet, as motivated in the introduction and in contrast to BGM, we allow both players to terminate the relationship and to trade with alternative partners if the other player defects, plus we assume costly renegotiation of the asset off the equilibrium path. Hence, our first contribution is to analyze how the choice between Integration and Outsourcing is affected by the introduction of optimal punishment and costly renegotiation. Second, in light of our general results, we study what happens if Joint Ownership is also a feasible option and hence analyze a "make-or-buy-or-collaborate" decision $\alpha \in \{\mathcal{I}, \mathcal{O}, \mathcal{J}\}$. Without loss of generality A is a single asset that stands for all assets that are valuable to the agent outside

[20] See for example the *Corruption Perceptions Index* (CPI) as a much cited measure which is published annually by Transparency International.

[21] For instance, Mischel and Ebbesen's (1970) famous Stanford marshmallow experiments have triggered many further experiments and resulted in an entire branch of literature in psychology.

the relationship if the remaining assets in all ownership structures belong to the principal whose outside payoff without the asset A is normalized to 0. Our interpretation of *Integration* $\mathcal{I}$ is that the principal owns the asset A and the agent is an employee.[22] We interpret *Outsourcing* as the case where the agent owns A that are potentially valuable outside the relationship. As before, by *Joint Ownership* we understand that A can only be used with both parties' consent.

6.1. Specification

Now only one player, say player $i = 1$ called the *agent* faces an effort decision $e \in E$ with cost $C(e,\omega)$ that affects the stochastic output $Q(e,\omega)$, the default distribution of output $q(e,\alpha,\omega)$ and his disagreement payoff $P_1(e,A,\omega) > P_1(e,\emptyset,\omega) = 0$.[23] For a single asset A we have $A_1, A_2, A_{12} \in \{a, \emptyset\}$, then $\mathcal{I} = (A_1, A_2, A_{12}) = (\emptyset, A, \emptyset)$, $\mathcal{O} = (A, \emptyset, \emptyset)$ and $\mathcal{J} = ((\emptyset, \emptyset, A)$. Denote the unique "no-effort-choice" of the agent by $e = 0$ with $C(0,\omega) = 0$. Player $i = 2$, called the *principal*, is inactive regarding production, i.e. $E_2 = \{0\}, C_2 = 0$. Still, her disagreement payoff outside the relationship $P_2(A,\omega) \geq P_2(\emptyset,\omega) = 0$ may be positive with the asset. The interpretation is that the principal hires a new agent once the relationship with player 1 has broken down if she owns the critical asset A. The agent's action e is private information, only its stochastic consequences $(Q(e,\omega), q(e,\alpha,\omega), P_1(e,A_1,\omega))$ are observed by both parties. To provide incentives to the agent towards the efficient cooperative action $e^c = \text{argmax}_e\, S(e)$, the principal offers a contract $\beta(\cdot) = s + b(Q,q,P)$ with a *fixed salary* s and a *variable bonus payment* $b(Q(e,\omega), q(e,\alpha,\omega), P_1(e,A_1,\omega))$. The latter may be contingent on performance, i.e. on the outcome of the variables observed by both parties. Clearly, independent of the ownership structure, for $\delta = 0$ the principal has no incentive to pay any bonus. This is anticipated by the agent who in the short run picks the opportunistic effort $e^d(\alpha) \in \text{argmax}_e\, \mathbb{E}\left[q_1(e,\alpha,\omega)Q(e,\omega) - C(e,\omega)\right]$, which corresponds to the holdup equilibrium in the general formulation.

6.2. Static game

As we study a principal-agent model, the default ownership of output under $\mathcal{I}$ is such that the principal owns everything including the output, i.e. $q_2(e,\mathcal{I},\omega) = 1$ and $q_1(e,\mathcal{I},\omega) = 0$. This implies that in the static game, $e^d(\mathcal{I}) = 0$. By contrast, under $\mathcal{O}$ and $\mathcal{J}$, critical assets can only be used with the consent of the agent. Hence, $q_1(e,\alpha,\omega) > 0$ for $\mathcal{J}$ and $\mathcal{O}$. E.g. under Nash bargaining, we would have $q_1(e,\mathcal{O},\omega)Q(e,\omega) = \frac{1}{2}\left[Q(e,\omega) + P_1(e,\mathcal{O},\omega)\right]$ and $q_1(e,\mathcal{J},\omega)Q(e,\omega) = \frac{1}{2}Q(e,\omega)$. Therefore, $e^d(\mathcal{O}) \neq 0$ and $e^d(\mathcal{J}) \neq 0$. Hence, $\mathcal{I}$ is not short-term efficient since output is minimal, which is consistent with BGM's results. Whether $\mathcal{O}$ or $\mathcal{J}$ is short term efficient for impatient players depends on the production technology.

6.3. Required liquidity

As the joint separation payoffs also the required liquidity depends on the production technology and we study both cases $\Delta^{\mathcal{O}} \geq \Delta^{\mathcal{I}}$ and $\Delta^{\mathcal{O}} < \Delta^{\mathcal{I}}$ for some equilibrium stationary action profile e. The analysis of the static game implies $\Delta^{\mathcal{J}} \leq \Delta^{\mathcal{I}}$ since $e^d(\mathcal{J}) \neq e^d(\mathcal{I}) = 0$. Under Joint Ownership, the agent always gets a positive share of the output, because all assets can only be used with his consent. Yet, he cannot raise his payoff by threatening to realize his disagreement payoff, because $P_1(e,\emptyset,\omega) = 0$. Further, since by Lemma 1 $\mathcal{J}$ minimizes $\bar{U}^0(\alpha)$, we have $\delta V(e;\mathcal{J}) \geq \delta V(e;\mathcal{I})$ for any e. This implies that within the principal agent model, studied here, any action e that can be implemented under *Integration* can also be implemented under *Joint Ownership*.

6.4. High Renegotiation Costs

The (joint) separation payoff of a relationship with ownership structure α that has broken down is given by

$$\begin{aligned}\bar{U}^0(\alpha) &= U^0(\alpha^R) - \frac{1-\delta}{\delta} z^0\left(RA\left(\alpha,\alpha^R\right)\right) \\ &= P_1\left(e^0,\alpha^R,\omega\right) + P_2\left(\alpha^R,\omega\right) - C\left(e^d(\alpha^R)\right) - \frac{1-\delta}{\delta} z^0\left(RA\left(\alpha,\alpha^R\right)\right),\end{aligned}$$

where again α^R denotes the *resulting* ownership structure after haggling over the assets. If A is inalienable or toxic or more generally $z^0\left(RA\left(\alpha,\alpha^R\right)\right) > \frac{\delta}{1-\delta}U^0(\alpha^R)$ renegotiation is prohibitively expensive and $\alpha^R = \alpha$. This is in particular the case if Joint Ownership is a Strict Coasian Institution and parties are sufficiently patient and thereby Theorem 2 applies.

Proposition 2. *Consider the relationship design problem $\{\mathcal{I},\mathcal{O},\mathcal{J}\}$. For prohibitively high renegotiation costs $\mathcal{J}$ is uniquely optimal and incentive maximizing for sufficiently patient players.* □

Proof. This follows by the same comparison as in the proof of Theorem 2. ■

If conversely renegotiation costs $z^0\left(RA\left(\alpha,\alpha^R\right)\right)$ are not prohibitively high Lemma 1 implies that $\bar{U}^0(\alpha)$ is minimized under *Joint Ownership*. Further, without additional assumptions, both cases $\bar{U}^0(\mathcal{I}) \leq \bar{U}^0(\mathcal{O})$ and $\bar{U}^0(\mathcal{I}) > \bar{U}^0(\mathcal{O})$ are possible in principle. Which

[22] BGM call the agent *upstream party*, the principal *downstream party*, and this case *employment*.

[23] We impose no restrictions on the choice set. It may well be a multitasking problem as in BGM.

case occurs depends on whether outside of the relationship, critical assets are more valuable in the hands of the principal or the agent.

6.5. Low renegotiation costs

Now we call renegotiation costs *low* if they are below the prohibitive barrier $z^0\left(RA\left(\alpha,\alpha^R\right)\right) \leq \frac{\delta}{1-\delta}\min\{U^0(\mathcal{I}),U^0(\mathcal{I})\}$. In this case parties after a breakup always prefer to renegotiate ownership if it is not yet ex-post efficient.

Proposition 3. *Consider any two ownership structures in $\{\mathcal{I},\mathcal{O},\mathcal{J}\}$ and let renegotiation costs be low.*

1. *For the relationship design problem $\{\mathcal{I},\mathcal{J}\}$, Joint Ownership is optimal and incentive maximizing for any $\delta\in(0,1)$.*
2. *For the relationship design problem $\{\mathcal{O},\mathcal{J}\}$, Joint Ownership is always optimal and incentive maximal if $\Delta^{\mathcal{J}}\leq\Delta^{\mathcal{O}}$. If $\Delta^{\mathcal{J}}>\Delta^{\mathcal{O}}$, outsourcing is optimal and incentive maximal if and only if $\Delta^{\mathcal{J}}\frac{V^{\mathcal{O}}}{V^{\mathcal{J}}}\geq\Delta^{\mathcal{O}}$*
3. *In relationship design problem $\{\mathcal{I},\mathcal{O}\}$, each of the two ownership structures can yield the higher relationship value. This implies that in principle all four potential cases can be relevant:*

   (i) $V^{\mathcal{I}}\geq V^{\mathcal{O}}$ *and* $\Delta^{\mathcal{I}}\leq\frac{V^{\mathcal{I}}}{V^{\mathcal{O}}}\Delta^{\mathcal{O}}$*: $\mathcal{O}$ is optimal for $\delta=0$ and $\mathcal{I}$ is optimal and incentive maximal if e^c can be implemented,*

   (ii) $V^{\mathcal{I}}\geq V^{\mathcal{O}}$ *and* $\Delta^{\mathcal{I}}>\frac{V^{\mathcal{I}}}{V^{\mathcal{O}}}\Delta^{\mathcal{O}}$*: $\mathcal{O}$ is optimal and incentive maximal for $\delta=0$ as well as in the lower range of discount factors $\delta\in\left[0,\delta_1\right]$ where e^c can be implemented and $\mathcal{I}$ is optimal and incentive maximal in the upper range $\delta\in\left[\delta_1,1\right]$ with critical discount factor $\delta_1=\frac{\Delta^{\mathcal{I}}-\Delta^{\mathcal{O}}}{\Delta^{\mathcal{I}}-\Delta^{\mathcal{O}}+V^{\mathcal{I}}-V^{\mathcal{O}}}$,*

   (iii) $V^{\mathcal{I}}<V^{\mathcal{O}}$ *and* $\Delta^{\mathcal{I}}\leq\frac{V^{\mathcal{I}}}{V^{\mathcal{O}}}\Delta^{\mathcal{O}}$*: Here $\mathcal{I}$ is optimal and incentive maximal for $\delta=0$ and $\mathcal{O}$ is optimal and incentive maximal if e^c can be implemented,*

   (iv) $V^{\mathcal{I}}<V^{\mathcal{O}}$ *and* $\Delta^{\mathcal{I}}>\frac{V^{\mathcal{I}}}{V^{\mathcal{O}}}\Delta^{\mathcal{O}}$*: $\mathcal{I}$ is optimal and incentive maximal for $\delta=0$ as well as in the lower range of discount factors $\delta\in\left[\underline{\delta},\delta_2\right]$ where e^c can be implemented and now $\mathcal{O}$ is optimal and incentive maximal in the upper range $\delta\in\left[\delta_2,1\right]$, now with critical discount factor $\delta_2=\frac{\Delta^{\mathcal{O}}-\Delta^{\mathcal{I}}}{\Delta^{\mathcal{O}}-\Delta^{\mathcal{I}}+V^{\mathcal{O}}-V^{\mathcal{I}}}$.* □

The first two statements relate Joint Ownership to any of the two other ownership structures and are novel since BGM did not include this comparison in their analysis. We knew already from our general results that Joint Ownership is optimal and incentive maximizing once agents are sufficiently patient. Here we see that Joint Ownership always dominates integration for the very reasons discussed above. This observation implies that in order to find the optimal and incentive maximizing ownership structure we need to compare Joint Ownership with Outsourcing. As we pointed out in section 2 in this comparison the tradeoff between relationship value and required liquidity enters. Joint Ownership turns out to be not optimal and incentive maximizing if players are less patient and the required liquidity under Outsourcing if $\Delta^{\mathcal{O}}$ is below $\Delta^{\mathcal{J}}\frac{V^{\mathcal{O}}}{V^{\mathcal{J}}}$. This is in particular the case when the agent's action has a strong positive impact on his outside payoff which cannot be realized under Joint Ownership. Conversely if the agent can engage in rent-seeking as in our numerical example, Joint Ownership will be optimal and incentive maximizing. The third statement performs BGM's comparison between Outsourcing and Integration, albeit within our strategic setting with optimal punishment. The result is not identical but similar to BGM in the sense that they also find that both possibilities can occur depending on further specification.

Since our off-equilibrium punishments are optimal penal codes we can measure the strength of the incentives with respect to the relative positions of the relationship value and the required liquidities. Our numerical example in section 2 which could also be interpreted as a principal agent relationship has shown, that for more general action spaces even short term results can be overturned. The current characterization shows that everything depends on the relative positions of the relationship values and the required liquidities. As we have seen before, this in turn depends on (i) where the critical assets are more valuable once the relationship breaks down, and (ii) whether we study a multitasking environment or a one-dimensional effort variable. To sum up, the three statements together establish in line with Theorem 2 that if all three options are available, Joint Ownership always provides optimal incentives if players are sufficiently patient.[24] If they are not patient enough, optimal incentives are characterized by the third statement of the proposition.

7. Related literature

In this section, we review the most relevant parts of the immense literature on the role of property rights in the context of designing successful relationships and explain in more detail the deviations of our present theory from the existing literature.

This project certainly rests very much on the transaction cost approach going back to Coase (1937, 1960) and Williamson (1981) and especially to a reverse interpretation of the Coase Theorem. Garvey (1995), Baker et al. (2001, 2002) and Halonen (2002) were among the first to analyze the role of property rights in ongoing relationships. Baker et al. (2001, 2002) compare Integration where a principal owns all assets with Outsourcing under which the agent owns some asset in a repeated principal-agent model,

[24] The critical discount factor $\tilde{\delta}$ is defined precisely by (25) in the proof of Proposition 3.

where incentives are provided by relational contracts. They find that ownership matters as it affects players' incentives to honor the relational contract. Our analysis extends their work on several grounds, overturning some of their results and confirming others. We relax the assumption of costless renegotiation of ownership, which simplifies their analysis but precludes ownership from affecting the relationship value. Further, we allow for optimal punishment considering strategies other than Nash reversion, as these imply that parties would not optimize with respect to the dynamic incentive structure that supports cooperation. Finally, we extend Baker et al.'s comparison between Outsourcing and Integration by adding the option of Joint Ownership. We find that Joint Ownership dominates Integration for any level of patience. By contrast, whether Joint Ownership or Outsourcing is optimal depends on the specific strategic setting.

Halonen (2002) is one of the first and the most influential contribution that studied Joint Ownership in a dynamic context. She considers a one-shot game as in Hart and Moore (1990) that is played repeatedly with deviations being punished by Nash reversion. She shows that in the static framework Joint Ownership is always inefficient. However, this downside turns out to be an upside in the repeated setting with perfect monitoring and side payments since under Nash reversion, the most inefficient ownership structure constitutes the most severe punishment, thereby creating the strongest incentives to cooperate. In her framework this tradeoff is solved in favor of one or the other ownership structure depending on the elasticity of the cost of investment. Our present article identifies several restrictions with this line of reasoning. First, the inefficiency of Joint Ownership in the stage game is specific to the setting studied by Hart and Moore and Halonen. Akin to the finding by Cai (2003), in section 2 we show in a simple numerical example where a player may also choose a rent-seeking action that Joint Ownership may in fact be more efficient than private ownership already in the static game. Conversely, under Nash reversion off the equilibrium path, private ownership would be more efficient than Joint Ownership in a repeated game, turning Halonen's result upside down. An analogous reversal of Halonen's observations results if the stage game allowed parties to endogenously choose the degree of specificity of their investments, as in Cai (2003). In this paper, we assume that off the equilibrium path, players do not revert to the Nash equilibrium which is no optimal penal code but instead terminate the relationship which is an optimal punishment.

More precisely, our analysis shows that with a more general action space and optimal punishment, Joint Ownership may be the second best efficient static ownership structure as well as the one that creates the strongest cooperation incentives for patient players compared to all other cases. The tradeoff identified in Halonen is therefore dependent on the restrictive action set and suboptimal strategies adopted in her model. By contrast, we find that Joint Ownership need not entail a tradeoff between short- and long-run incentives to cooperate. Halonen (2002) allows for renegotiation of ownership at a fixed cost, ignoring the effect of ownership onto the cost of renegotiation.

Garvey (1995) also analyzes the role of ownership in a repeated trade model with perfect monitoring and a specific cost function and production technology. However, his model imposes an exogenous, non-optimal transfer, while we allow players to choose the contingent side-payment optimally. For this reason, Garvey's conclusion that optimal ownership rights should be symmetric across firms is not confirmed in our framework.

While focusing on optimal ownership in relational contracts, our model borrows heavily from various methods developed for analyzing general models of relational incentive contracts. Malcomson (2013) provides a comprehensive survey of the literature on relational incentive contracts. We use techniques developed by Levin (2003) and Goldlücke and Kranz (2012) for repeated imperfect monitoring settings. We also contribute to the literature that studies how certain aspects of relationships should be designed so as to improve and facilitate relational incentive contracts. Within this strand, Rayo (2007) examines a repeated moral-hazard-in-teams model and studies to what extent different profit-sharing rules can improve the effectiveness of relational incentives. Che and Yoo (2001) analyze what form of performance evaluation best supports the implicit contract among members of a production unit. Baker et al. (1994), Bernheim and Whinston (1998), Kvaloy and Olsen (2009), Pearce and Staccetti (1998) and Schmidt and Schnitzer (1995) look at how explicit contracts and formal incentives should be designed so as to optimally support and complement existing implicit contracts. Li and Matoushek (2013) study how periodically arising conflicts in repeated principal-agent relationships should be managed. Furthermore, Halac (2015) analyzes how an ex-ante unilateral and irreversible investment by one party affects that party's ability to sustain a relational contract under different informational assumptions.

Finally, in a related paper, Miller and Watson (2013) study behavior in repeated games when players can bargain over the choice of the continuation equilibrium.[25] They find that the distribution of bargaining power has important implications for the choice of continuation play and hence for the set of allocations that can be sustained by relational contracts. Our model is more specific as different ownership structures and allowing for nonzero haggling costs establish different allocations of bargaining power.

8. Conclusion

In this paper, we provided a general framework for comparing arbitrary ownership forms with respect to improving incentives for cooperation in ongoing business relationships. We extended the existing literature on ownership in relational settings in two major ways. First, we assumed that any observed deviation from prescribed behavior triggers severance of the relationship. This ensured that punishments were optimal. Second, our concept of *(strict) asset renegotiation monotonicity* posits that the costs of renegotiating ownership (strictly) increase in the number of assets subject to renegotiation. In this framework, Joint Ownership has a fundamental advantage over any other ownership structure as it minimizes players' joint continuation payoff following a separation and is the unique such ownership structure in the strict case. Consequently, Joint Ownership is optimal if either the required liquidity is constant

[25] See also Goldlücke and Kranz (2013), who study how different concepts of renegotiation-proofness apply to relational contracts.

as for perfect monitoring or if renegotiation costs cause an inefficient outcome in case of a breakup. Further, the range of discount factors for which incentives are optimal increases in the (unit-) costs of renegotiation. We have shown with a numerical example that the logic of our results as well as the predictions differ fundamentally from the previous literature as for example Halonen (2002). Moreover, we showed for a principal agent environment with moral hazard that at intermediate and lower levels of the discount factor the optimal ownership depends on the specification of the technological environment. In particular, we applied our approach to the principal-agent relationship studied by Baker et al. (2002). We generalized this framework and studied the performance of Joint Ownership within this context, showing that Joint Ownership always dominates Integration, which can hence be eliminated from the set of ownerships structures that potentially maximize the joint surplus.

There are other features that we could not consider and that may be important to fully understand the role of ownership in dynamic environments. For example, it seems important that future work considers robustness issues, like the amount of strategic risk cooperative relationships imply under different ownership structures (see Blonski et al., 2011, Blonski and Spagnolo, 2015) and their resilience to exogenous shocks and ability to adapt to changing environments (see Baker et al., 2011). Indeed, incorporating these additional issues appears to be an interesting avenue for future research in this field.

Declaration of competing interest

We are not aware of any conflicts of interest.

Data availability

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

Appendix

Proof (of Lemma 1). The following sequence of inequalities prove the claim of the lemma.

$$
\begin{aligned}
\bar{U}^0(\alpha^J) &= U^0(\alpha^R(\alpha^J)) - \frac{1-\delta}{\delta} z^0(\alpha^J, \alpha^R(\alpha^J)) && (20)\\
&\le U^0(\alpha^R(\alpha^J)) - \frac{1-\delta}{\delta} z^0(\alpha, \alpha^R(\alpha^J)) && (21)\\
&\le U^0(\alpha^R(\alpha)) - \frac{1-\delta}{\delta} z^0(\alpha, \alpha^R(\alpha)) && (22)\\
&= \bar{U}^0(\alpha). && (23)
\end{aligned}
$$

The two equations (20) and (23) are just the definition (7) of $\bar{U}^0$.

For the first inequality (21) note that by definition of Joint Ownership all assets that are used ex-post have to be renegotiated, or $RA(\alpha, \alpha^R(\alpha^J)) \subseteq RA(\alpha^J, \alpha^R(\alpha^J))$. Renegotiation Asset Monotonicity then implies $z^0(\alpha, \alpha^R(\alpha^J)) \le z^0(\alpha^J, \alpha^R(\alpha^J))$ which in turn implies the first inequality.

The second inequality (22) follows since by its definition (6) $\alpha^R(\alpha)$ is an optimal ex-post ownership structure after renegotiation starting from ex-ante ownership structure α. ■

Proof (of Lemma 3). By definition (13) the required liquidity satisfies $\Delta(e,\alpha) \le \bar{\beta}_1(e,\alpha) + \bar{\beta}_2(e,\alpha)$ and adding up conditions (12) for both players yields

$$
\begin{aligned}
\Delta(e,\alpha) &\le \frac{\delta}{1-\delta}\left[u_1(e,\alpha) + u_2(e,\alpha) - \mathbb{E}\left[\beta_1(e,\alpha)\right] - \mathbb{E}\left[\beta_2(e,\alpha)\right] - u_1^0(\alpha) - u_2^0(\alpha)\right]\\
&\le \frac{\delta}{1-\delta}\left[S(e,\alpha) - \bar{U}^0(\alpha)\right]\\
&= \frac{\delta V(e,\alpha)}{1-\delta}.
\end{aligned}
$$

If the converse inequality $\delta V(e,\alpha) - (1-\delta)\Delta(e,\alpha) < 0$ holds, then there is no side payment function β such that condition (12) holds for both players $i \in \{1,2\}$. Therefore the dynamic enforcement constraint (16) is a necessary condition. To prove sufficiency, suppose that $\delta V(e,\alpha) - (1-\delta)\Delta(e,\alpha) \ge 0$. This implies there exist equilibrium side payments β such that

$$
\begin{aligned}
\Delta(e,\alpha) \le \bar{\beta}_1(e,\alpha) + \bar{\beta}_2(e,\alpha) &\le \frac{\delta}{1-\delta}\left[\sum_{i=1,2} u_i(e,\alpha) - \mathbb{E}\beta_i(e,\alpha) - u_i^0(\alpha)\right]\\
&\le \frac{\delta}{1-\delta}\left[S(e,\alpha) - \bar{U}^0(\alpha)\right].
\end{aligned}
$$

This implies that incentive condition (12) is satisfied for at least one of the two players. If condition (12) is satisfied for both players we are done. Suppose conversely without loss of generality that it is satisfied for player 1 but not satisfied for player 2, i.e.

$$
\bar{\beta}_2(e,\alpha) > \frac{\delta}{1-\delta}\left[u_2(e,\alpha) - \mathbb{E}\left[\beta_2(e,\alpha)\right] - u_2^0(\alpha)\right], \text{ for } i \in \{1,2\}.
$$

In this case define a shifted payment function $\beta^* := (\beta_1^*, \beta_2^*) = (\beta_1 + \psi, \beta_2 - \psi)$ with

$$\psi := \bar{\beta}_2(e,\alpha) - \frac{\delta}{1-\delta}\left[u_2(e,\alpha) - \beta_2(e,\alpha) - u_2^0(\alpha)\right] \tag{24}$$

For the shifted payment function β^* the incentive compatibility constraints (11) remain the same. But now by definition (24) of ψ we obtain

$$\bar{\beta}_2^* = \frac{\delta}{1-\delta}\left[u_2(e,\alpha) - \beta_2(e,\alpha) - u_2^0(\alpha)\right]$$
$$\bar{\beta}_1^* < \bar{\beta}_1 \le \frac{\delta}{1-\delta}\left[u_1(e,\alpha) - \beta_1(e,\alpha) - u_1^0(\alpha)\right].$$

Together this shows that the dynamic enforcement constraint (16) is sufficient to make sure that there exist equilibrium side payments β^* implementing e, i.e. for which condition (12) and incentive compatibility constraints (11) are satisfied. ■

Proof (of Theorem 1). Consider any optimal ownership structure α satisfying the dynamic incentive constraint $\delta V(\alpha) - (1-\delta)\Delta(\alpha) \ge 0$ for the efficient action profile e^c. With assumption (17) α^* provides stronger incentives than α if and only if

$$\delta V(\alpha^*) - (1-\delta)\Delta(\alpha^*) \ge \delta V(\alpha) - (1-\delta)\Delta(\alpha) \Leftrightarrow$$
$$\delta\left(S^* - U^0(\alpha^R(\alpha^*)) + \frac{1-\delta}{\delta}z^0(\alpha^*,\alpha^R(\alpha^*))\right) - (1-\delta)\Delta(\alpha^*) \ge$$
$$\delta\left(S^* - U^0(\alpha^R(\alpha)) + \frac{1-\delta}{\delta}z^0(\alpha,\alpha^R(\alpha))\right) - (1-\delta)\Delta(\alpha) \quad \Leftrightarrow$$
$$z^0(\alpha^*,\alpha^R(\alpha^*)) - \Delta(\alpha^*) - \frac{\delta}{1-\delta}U^0(\alpha^R(\alpha^*)) \ge$$
$$z^0(\alpha,\alpha^R(\alpha)) - \Delta(\alpha) - \frac{\delta}{1-\delta}U^0(\alpha^R(\alpha)). \quad ■$$

Proof (of Theorem 2). Similarly as in the proof of Theorem 1 consider any optimal ownership structure α satisfying the dynamic enforcement constraint $\delta V(\alpha) - (1-\delta)\Delta(\alpha) \ge 0$ for the efficient action profile e^c. With assumption (17) α^J provides stronger incentives than α if and only if

$$\delta V(\alpha^J) - (1-\delta)\Delta(\alpha^J) > \delta V(\alpha) - (1-\delta)\Delta(\alpha) \Leftrightarrow$$
$$\frac{\delta}{1-\delta}\left(U^0(\alpha^R(\alpha)) - U^0(\alpha^R(\alpha^J))\right) > z^0(\alpha,\alpha^R(\alpha)) - z^0(\alpha^J,\alpha^R(\alpha^J)) + \Delta(\alpha^J) - \Delta(\alpha),$$

which holds by inequality (8) for sufficiently large δ since Joint Ownership is a Strict Coasian Institution. ■

Proof (of Theorem 4). Using definitions (7) and (9) the relationship value of α is

$$V(e,\alpha) = S(e,\alpha) - \bar{U}^0(\alpha)$$
$$= S(e,\alpha) - U^0(\alpha^R(\alpha)) + \frac{1-\delta}{\delta}z^0(RA)$$

for a given set of renegotiation assets RA. Hence, the dynamic enforcement constraint (16) from page 11 is equivalent to

$$\delta \ge \underline{\delta}(e,\alpha) = \frac{\Delta(e,\alpha) - z^0(RA)}{S(e,\alpha) - U^0(\alpha^R(\alpha)) + \Delta(e,\alpha) - z^0(RA)}$$

where $\underline{\delta}(e,\alpha)$ is the lower bound on discount factors for which action profile e can be implemented under α. By definition (19) on page 12 bigger renegotiation costs mean that $z^0(RA)$ increases for any $RA \subset A$. Therefore, $\underline{\delta}(e,\alpha)$ ceteris paribus decreases with bigger renegotiation costs $z^0(RA)$. ■

Proof (of Corollary 1). First note that for sufficiently large δ and finite renegotiation costs z^0 any ownership structure α will be renegotiated to the same aggregated outside per period payoff U^0 defined by (1) after a breakdown of the relationship. To see this consider the converse case where $U^0(\alpha_1) > U^0(\alpha_2)$. Since in this case $\frac{\delta(U^0(\alpha_1)-U^0(\alpha_2))}{1-\delta} > z^0$ for sufficiently large δ and finite z^0 it would be a strict gain for both parties to renegotiate from $\alpha^R(\alpha_2)$ to $\alpha^R(\alpha_1)$ which contradicts definition (6) of $\alpha^R(\alpha_2)$ to be optimal. Moreover, for a similar reason the maximal surplus S^* can be implemented with the stationary action profile $e^c = \left(e_1^c, e_2^c\right)$ for any ownership structure. This implies that for sufficiently large δ all ownership structures yield optimal surplus in the repeated setting. Now let $z^0(\alpha)$ denote the renegotiation cost to renegotiate from α to an ownership structure that yields U^0 after breakdown. With this notation the condition for the incentive maximizing ownership structure α^* turns

$$\delta V(e^c,\alpha^*) - (1-\delta)\Delta(\alpha^*) \ge \delta V(e^c,\alpha') - (1-\delta)\Delta(\alpha') \Leftrightarrow$$
$$\delta\left(S^* - U^0 + \frac{1-\delta}{\delta}z^0(\alpha^*)\right) - (1-\delta)\Delta(\alpha^*) \ge \delta\left(S^* - U^0 + \frac{1-\delta}{\delta}z^0(\alpha')\right) - (1-\delta)\Delta(\alpha') \Leftrightarrow$$

$$z^0(\alpha^*) - \Delta(\alpha^*) \geq z^0(\alpha') - \Delta(\alpha'),$$

for all α' which proves the statement. ■

Proof (of Proposition 1). As δ gets arbitrarily close to zero, for any action profile e, $\delta V(e,\alpha) - (1-\delta)\Delta(e,\alpha)$ goes to $-\Delta(e,\alpha)$. Thus, the aggregated incentive is strictly negative for any action profile other than the unique hold-up Nash equilibrium. Therefore, by Lemma 3, no action profile other than the hold-up equilibrium, $e^d(\alpha)$, can be implemented. Moreover, for $e^d(\alpha)$, $\delta V(e,\alpha) - (1-\delta)\Delta(e,\alpha) = 0$. This implies that any short-term efficient ownership structure $\widehat{\alpha} \in \widehat{A}$ maximizes the implementable surplus.[26] ■

Proof (of Proposition 3). In each of the three binary comparisons we make use of the following structure. Let $\alpha_1, \alpha_2 \in \{\mathcal{I}, \mathcal{O}, \mathcal{J}\}$ where α_1 is ownership with the larger relationship value $V^1 \geq V^2$. Further, since money burning was excluded by assumption (and would not be optimal anyway if allowed), the critical discount factor $\underline{\delta}(e^c, \alpha_i)$ such that for all $\delta \geq \underline{\delta}(e^c, \alpha_i)$, e_c can be implemented, is given by $\underline{\delta}(e^c, \alpha_i) \equiv \delta_i = \frac{\Delta^i}{\Delta^i + V^i}$. By definition, for $\delta < \underline{\delta} = \min\{\frac{\Delta^1}{\Delta^1+V^1}, \frac{\Delta^2}{\Delta^2+V^2}\}$ cooperation e^c cannot be implemented. Then, to prove all the claims of the proposition we use the following auxiliary results.

A1 Ownership α_2 is always short-term efficient. This follows from $V^1 \geq V^2 \Rightarrow U^0(\alpha_2) \geq U^0(\alpha_1)$ and the joint holdup equilibrium surplus which in this setup is given by $U^0(\alpha)$.

A2 If the required liquidity of α_1 is sufficiently small, i.e. $\Delta^1 \leq \tilde{\Delta}$, then α_1 always provides optimal incentives for all $\delta \geq \underline{\delta} = \delta_1$ where the critical required liquidity is given by $\tilde{\Delta} = \frac{V^1}{V^2}\Delta^2 \geq \Delta^2$. This follows from $\Delta^1 \leq \tilde{\Delta}$ and $V^1 \geq V^2 \Rightarrow \delta V^1 - (1-\delta)\Delta^1 \geq \delta V^2 - (1-\delta)\Delta^2$ for $\delta \geq \underline{\delta} = \delta_1$.

A3 If, conversely, the required liquidity of α_1 is above the critical level $\Delta^1 > \tilde{\Delta}$ then both ownership structures can provide optimal incentives. Specifically, α_2 provides optimal incentives in the lower range of discount factors $\delta \in [\underline{\delta}, \tilde{\delta}]$ and α_1 provides optimal incentives in the upper range $\delta \in [\tilde{\delta}, 1]$ where the critical level of patience is given by

$$\tilde{\delta} = \frac{\Delta^1 - \Delta^2}{\Delta^1 - \Delta^2 + V^1 - V^2} > \delta_1 > \delta_2 = \underline{\delta} \tag{25}$$

This follows by $V^1 \geq V^2$ together with

$$\begin{aligned}
\tilde{\delta}V(e,\alpha_1) - (1-\tilde{\delta})\Delta(e,\alpha_1) &= \tilde{\delta}V^1 - (1-\tilde{\delta})\Delta^1 \\
&= \frac{(\Delta^1 - \Delta^2)V^1}{\Delta^1 - \Delta^2 + V^1 - V^2} - \left(1 - \frac{\Delta^1 - \Delta^2}{\Delta^1 - \Delta^2 + V^1 - V^2}\right)\Delta^1 \\
&= \frac{\Delta^1 V^2 - \Delta^2 V^1}{\Delta^1 - \Delta^2 + V^1 - V^2} \\
&= \frac{(\Delta^1 - \Delta^2)V^2}{\Delta^1 - \Delta^2 + V^1 - V^2} - \left(1 - \frac{\Delta^1 - \Delta^2}{\Delta^1 - \Delta^2 + V^1 - V^2}\right)\Delta^2 \\
&= \tilde{\delta}V^2 - (1-\tilde{\delta})\Delta^2 \\
&= \tilde{\delta}V(e,\alpha_2) - (1-\tilde{\delta})\Delta(e,\alpha_2).
\end{aligned}$$

Claim 1 of the proposition then follows from Lemma 1, i.e. $V^{\mathcal{J}} \geq V^{\mathcal{I}}$ and $\Delta^{\mathcal{J}} \leq \Delta^{\mathcal{I}}$ together with auxiliary results A1 and A2. Claim 2 of the proposition follows again from Lemma 1, i.e. $V^{\mathcal{J}} \geq V^{\mathcal{O}}$ together with auxiliary results A1, A2 and A3. By applying both cases $V^{\mathcal{I}} \geq V^{\mathcal{O}}$ and $V^{\mathcal{I}} < V^{\mathcal{O}}$ to claims A1, A2 and A3, we obtain all 4 subcases of Claim 4. ■

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[26] Note that by our definition of optimality $\widehat{\alpha}$ is surplus maximizing but not optimal as S^c cannot be implemented for sufficiently low δ.

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