Essays in the Economic Analysis of Corporate and Public Law

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Michael Hewer
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Dekan:	Prof. Dr. Klaus Sandmann
Erstreferent:	Prof. Dr. Urs Schweizer
Zweitreferent:	Prof. Dr. Hendrik Hakenes

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Introduction

After working for nearly four years on my doctoral thesis, I'm eager to refrain from just describing what I did in the papers this thesis is based on and what their relevance for scholars might be. Firstly, because I hope that my co-author and I manage to explain the importance of our work already in these chapters. Secondly, it would be too short-sighted to limit my insights and knowledge gained at the Bonn Graduate School of Economics to the three chapters collected in this thesis. Therefore, let me explain, how my research ideas evolved, which deviations I was obliged to take, and how fully-fledged research papers grew.

The first two chapters of this thesis are in the area of "law and economics". The third chapter has quite a few links to the law and economics literature. So what, in a nutshell, is "law and economics"? What distinguishes this field from others?

Law and economics is sometimes also referred to as "economic analysis of law". It started with analyzing antitrust law, regulated industries, tax, and the determination of monetary damages (Cooter and Ulen (2011), p.1). Apparently, lawmakers appreciated the insights gained with the help of economic methods. Therefore, law and economics quickly extended to nearly all subjects of law, such as criminal law and property law. Law and economics has a descriptive and a normative aspect: The descriptive one evaluates real-world institutions, while the normative view examines how an ideal law looks like in a given environment (Shavell (2004), pp. 1-5).

If I was forced to say what was really the core problem of law and economics, I would certainly point to the incompleteness of contracts.

But then, what makes law and economics different from contract theory? Law should constitute a set of rules that rational parties would have stipulated ex ante if it had been possible to agree on a contract. This view fits especially for the economic analysis for breach remedies, where the law constitutes default rules.[1] But also other domains re-construct efficient agreements. For example, tort law can also be seen as a contract between all possible injurers and all possible victims. The more parties involved, the more difficult it is to reach ex ante agreements and the more important the legal rules become. This also explains, why contract law, which typically deals with relationships between two persons, is only a set of default rules, while property, tort, or corporate law, which typically deal with relationships between more parties, are mandatory.

In my view, law and economics is a fascinating topic. One cannot overestimate the importance of real-world institutions such as contracts or the right to own property. Failure in such institutions is considered to be a major obstacle to economic development in poor countries (see, e.g., Levine (1999)). Being trained both as a lawyer and as an economist, this was "my field". I gained my first insight into this field during a lecture by Professor Winand Emons from Bern University. Therefore, I wanted to do research in law and economics. I was happy to have the opportunity to join the Bonn Graduate School of Economics with its amazing interdisciplinary research environment.

The first chapter is about the economic analysis of bankruptcy law. In an asymmetric information model, I show that law should give priority to stakeholders which are uninformed about the firm's characteristics in bankruptcy. The second chapter considers a topic in public law: In most legal systems, the state has the power to unilaterally extract private persons' property. It shows how optimal compensation should look like in order to induce efficient ex ante investments by the landowner and the government. The third chapter examines a model, where a seller is to purchase perfect complements from several buyers and shows that there

[1] Cooter and Ulen (2011), pp. 292-294, Schäfer and Ott (2005), pp. 403-419.

may be a complete breakdown of negotiations.

At this point, the reader may ask: What do these chapters have in common? Is this thesis a sample of three chapters that don't have anything to do with each other? My answer to this is: No, they do have a lot in common and this despite the fact that they belong to other strands of literature.

The world in each of the chapters is a world of incomplete contracts, which shows the connection to the core problem of law and economics. In chapter I, by assumption, the parties cannot agree on the bankruptcy rule which maximizes their joint surplus. This seems realistic in this framework, because there are three players and in reality, typically even more parties are involved in the bankruptcy procedure. Chapter II only considers two parties. But in principle, every citizen may be victim of a taking. This makes it too costly or even impossible for the government to contract with every possible victim of a taking. Chapter I and II have in common that they re-construct the optimal contract.

The third chapter also considers a setting with at least three involved parties. It adopts the assumption of Cai (2000) and assumes that the parties can only make binding cash-offer contracts. While the impact of more complex contracts is not clear at first glance, the social optimum would certainly be attainable if all involved parties could write a complete contract. Concerning the eminent domain literature, we can deduce from this chapter is that the government should be entitled to take the private property without the owner's consent. But also in corporate law, this effect can be relevant: An (efficient) takeover of a firm or an (efficient) restructuring of a firm's debt may fail due to the large number of involved parties. Hence, we also provide an argument for mandatory squeeze-out and bankruptcy rules.

Therefore, in all three chapters, the problem studied arises because the parties cannot reach the first best with the help of contracts. Hence, there is a need for mandatory rules in order to reach the social optimum. This seems especially plausible for settings with many (potentially) involved parties.

Information and Priority Rules

The research idea behind chapter I can be traced back to the beginning of my doctoral studies in Bonn. In my law studies at the University of Freiburg I had heard about the equitable subordination doctrine. Under German law, shareholder loans are subordinated in bankruptcy. I knew that there was a legal debate about this rule because its consequences were unknown. In other legal systems, any kind of insiders may suffer from the rule. I thought that the impact of the equitable subordination doctrine was far from obvious.

I was looking for papers in this area. One of the few papers in this area was Gelter (2006), which examines a moral hazard-related approach. This approach, however, yields ambiguous results:

> *"Even though subordination has some beneficial effects, it deters some desirable rescue attempts and is an insufficient deterrent for some undesirable ones. Legal reform should thus focus on narrowing down the scope of application to undesirable shareholder loans, where more severe penalties than subordination should apply."*
>
> — *Martin Gelter*

For example, consider a firm with some external creditor and an investment opportunity. This investment may be efficient or inefficient. Without the subordination doctrine, the investment would be financed with a credit because this dilutes the other creditor's claim in the event of bankruptcy. Hence, even if the investment is inefficient, the coalition of the owner and a new creditor may gain in expectation. A subordination rule can solve this incentive problem by giving priority to the first creditor's claim.

But this argument has two major problems: Firstly, as noted by Gelter (2006), the subordination rule can also deter efficient investments. This is the case if the value of the first creditor's claim is increased to the investment and the increase is larger than the overall net surplus of the investment. Hence, at first glance, it is not clear whether this rule has desirable or undesirable consequences.

Secondly, one cannot explain why this rule should only be applied to those who are somehow defined insiders of the firm. The described problem is a general one in corporate finance. Given a relationship between a debtor and an (old) creditor, the debtor always has an incentive to issue more debt instead of equity because the old creditor's claims in bankruptcy are diluted to some extent. The solution to this problem is certainly an interesting topic in contract theory and corporate finance, but it is not specific to the equitable subordination doctrine. Any rule that stipulates a priority ordering according to the point in time when the credit was issued would probably be impractical and could deter socially desirable investment as the value of the old creditor's claims could be increased.

The scarcity of economic analyses is quite surprising, given that the equitable subordinations doctrine is prevalent in the real world and because the number of cases is increasing (Claussen (1996)). Because the effects of the equitable subordination doctrine was still not very well understood, I decided to examine another justification for the equitable subordination doctrine: In contrast to Gelter (2006), my study focuses on an asymmetric information model. I want to investigate which priority regime was best in a world where the creditors had different information about the firm. The German law allows only the subordination of owner loans. Nevertheless, to accurately disentangle the role of superior information from the role of control of the firm, I model two creditors. Furthermore, under U.S. law, the subordination of credits issued by third parties is possible, too.

I was looking for a model that considered the interplay of several creditors in such a situation. The literature so far focuses on the importance of collaterals in credit markets with imperfect information. Prominent examples are Bester (1985) and Bester (1987). Other papers show how a right to liquidate the firm's assets to the creditor can avoid ex post opportunistic behavior by the entrepreneur (Berglöf and von Thadden (1994)), Bebchuk and Fried (1996)). However, those papers are not about ex ante asymmetric information and hence, the effect I wanted to show could not be deduced.

I set up a model that is similar in vain to Bolton and Scharfstein (1990). In the model, there is an entrepreneur who wants to conduct a one-period project, which can either yield a high or a low cash flow. The low cash flow is less than the initially invested financial means, i.e., bankruptcy occurs. The entrepreneurs differ with respect to their individual success probability. In the social optimum, all projects with positive expected net cash flow are carried out.

The entrepreneur needs financing from two creditors in order to start the project. One of the creditors is uninformed about the entrepreneur's characteristics. In the chapter, welfare is only a function of the set of realized projects. The chapter compares different priority rules with respect to their welfare implications.

The chapter's finding is that too many projects are financed. However, the overinvestment is less severe if the uninformed creditor enjoys priority in bankruptcy. The second-best regime from a welfare perspective is a rule in which the bankruptcy payoff of each creditor is proportional to size of the credit of this creditor. As a benchmark, equity financing is considered. With equity financing, welfare is between the pro-rata rule and informed creditor's priority.

The intuition for the results is: The uninformed creditor must partly bear the costs for financing inefficient projects. The more the uninformed creditor gets in bankruptcy, the less is the extent to which she must fund inefficient projects.[2] At the one extreme, if the informed creditor receives her full loan back even in bankruptcy, all projects may be carried out. At the other extreme, consider a situation in which the uninformed creditor is perfectly insured against bankruptcy. Then the coalition of the entrepreneur and the informed creditor is in the position of a residual claimant and has therefore efficient financing incentives, which means that the first best is achieved. Under equity financing,

[2] Throughout the chapter, the entrepreneur is referred to as "he" and the creditors as "she".

the informed creditor's share in the low state of the world is between informed creditor's priority and the pro-rata rule, from which the aforementioned welfare ranking follows.

As mentioned, if the parties could agree to the efficient priority regime, a coercive legal rule would be unnecessary. However, ex post opportunistic behavior by the entrepreneur may render such agreements impossible and such agreements between two different creditors may also be impossible.

Economic Analysis of Taking Rules: the Bilateral Case

The nucleus of the second chapter of this thesis is based on one of the many fruitful discussions that I had with my colleague Daniel Göller. At the time, a large public debate surrounded the necessity of the new runway that was being constructed at Frankfurt Airport. One day, we stumbled on the case of Ticona, a German-American plastic manufacturer. Ticona had a factory very close to the new runway. There were worries that the proximity could lead to disasters in the event of a plane crash. The state government of Hesse threatened Ticona with expropriation. In the end, the airport paid for Ticona to be relocated to another industrial area.[3]

We were interested in the legal background of this story. From my law studies, I knew that the law makes it possible to unilaterally take private persons' property. However, in such cases the state has to pay a compensation that was to be determined by just consideration of interests. We looked into commentaries and found that this compensation is usually equivalent to the fair market value.

[3] To review the Ticona case, see "Fraport einigt sich mit Ticona" and "Kein Pappenstiel für Fraport", both Frankfurter Allgemeine Zeitung of 11/26/2006; "Punktlandung in Höchst", Frankfurter Allgemeine Zeitung of 09/23/2011; "Ticona feiert neues Werk und lobt Standort", Frankfurter Allgemeine Zeitung of 09/26/2011; "Chemiewerk räumt das Feld für die neue Landebahn", Welt of 06/15/2011; "Für Fraport ist eigentlich Ticona schuld", Frankfurter Rundschau of 12/09/2005.

We agreed that this could be a problem. Landowners may overinvest in their property because they know that they are fully insured against the risk of a taking. Concerning the Ticona case, there has been an ongoing debate whether this factory could stay there since the '60s. Nevertheless, Ticona seemed not to incorporate the risk of a taking, which underpinned the relevance of the overinvestment. We agreed that this was a valid and economically interesting point.

We had found an interesting topic with a great relationship to a current debate. We built a model where a private person that has to fear an expropriation can make some ex ante specific investment. We did indeed find that full compensation leads to overinvestment incentives. By contrast, a regime that awarded the full social surplus to the landowner leads to efficient investment incentives.

But very soon, we discovered an article published 27 years ago in the Quarterly Journal of Economics: Blume, Rubinfeld, and Shapiro (1984). This article had virtually the same topic, used a very similar model and, consequently, had very similar results. Their article is intended to be provocative because they claim that no compensation leads to efficient investment incentives. We had slightly different results, which, however, would not have been sufficient to warrant another article. Despite the fact that the problem we were thinking about seemed to be interesting for other scholars as well, we were rather disappointed. Time to start from scratch.

The Blume, Rubinfeld, and Shapiro (1984) article is not the only paper in this area. Many of them challenge an assumption Blume, Rubinfeld, and Shapiro (1984) use: The government always maximizes welfare. This phenomenon is referred to as "fiscal illusion". One notably example is Hermalin (1995). He states:

"In legal writing one motive for compensating a citizen for taken property is to restrain the state from the tyrannical use of its rights of regulation or eminent domain. That is, the state is assumed not to act benevolently but to act on behalf of the interest of the majority (i.e., the rest of society) while essentially ignoring the interest of the individual property owner."

— *Benjamin E. Hermalin*

We agreed that, in such situations, it made sense to consider not only investments by the landowner, but also by the government. Also in the airport-Ticona example, this is very natural: Not only Ticona had made investments prior to a possible taking. Also the airport had to invest resources for geological exploration. It had to find out how this new runway could be realized and what the approach paths had to look like. But also in other real-world examples this may well be the case: The government may have to explore how to use a certain area as a disposal site for nuclear waste. Essentially, we had to analyze a setting of bilateral investment.

Throughout the chapter, we assume that the landowner has no possibility to challenge the taking itself, but can only request due compensation from a court. In the main part of our work, we consider a situation in which the government suffers from fiscal illusion or is "non-benevolent". Naturally, any assumption about the government's behavior is arbitrary to some extent. But, in this framework, we reason that a non-benevolent government would maximize the difference between the project's value and due compensation. Firstly, such a government may pursue the interests of the voters' majority, hence ignore the interests of the landowner. Secondly, as it was the case in the Ticona-airport example, the government could act on behalf of a private entity that enjoys the project's value, but has also to pay due compensation.

If the government is indeed non-benevolent, all standard compensation regimes perform poorly. If the full fair market value is compensated, the taking decision by the government is efficient and it invests efficiently given the investment by the landowner. However, she is fully insured against a taking and has therefore an incentive to overinvest. In this sense, we are able to confirm the results of Blume, Rubinfeld, and Shapiro (1984).

Under the regime proposed by Blume, Rubinfeld, and Shapiro (1984), i.e., to pay no compensation to the landowner, a taking will always occur. This exactly reflects the fear of a "Leviathan" state. In the model, this naturally leads to inefficient decisions because the government takes the property even if the social is less than the private value. Given this, both the government and the landowner have efficient investment incentives. This implies that the landowner invests nothing.

Another compensation regime which has been proposed in previous articles is to grant the landowner the full social value of her property.[4] Among others, Hermalin (1995) proposes this compensation regime. In the setting of chapter II, this makes the government indifferent between a taking and leaving the property to the landowner. So, the efficient taking decision can at least be supported as an equilibrium. Moreover, as the landowner cannot influence the amount of compensation, she invests efficiently. However, as the government always has to pay the full social value, her ex post surplus is equal to zero. Therefore, she has no ex ante incentives to invest. Consequently, the airport would not invest at all in the exploration of the geological conditions of the area.

Chapter II finds an alternative solution that yields the social optimum: Due compensation should be equal to the property's value given that the landowner had invested efficiently. Then, the government would always take the property if the actual social value was higher than the property's value given that the landowner had invested efficiently. Given this ex post taking decision, the government invests the same amount as in the social optimum independent of what the landowner does. The landowner can neither influence the probability of a taking nor the amount of due compensation. Therefore, she has efficient investment incentives given the investment by the government.

The solution is related to the notion of "efficient expectation damages" in Cooter (1985), but extends this to a bilateral setting. Besides its elegance, it has its drawbacks. It requires the court to calculate the optimal investment from an ex ante perspective.

As a benchmark, the case of a benevolent government is considered. This means that the government takes the land whenever the social ex-

[4]The government is referred to as "it", the landowner is a "she".

ceeds the private value of the property. In this case, only the landowner's decision problem needs to be analyzed. The government plays the socially optimal response to any investment of the landowner. If the landowner invests the socially optimal amount, we reach the social optimum. In order to make the landowner invest efficiently, compensation must be equal to the social value of the project. Under this compensation regime, the landowner's surplus is identical to welfare. Under any other commonly proposed regime, she overinvests in private property. She does so for two reasons: Firstly, she may increase her compensation in case of a taking. Secondly, she can reduce the probability of a taking.

What makes this chapter special, is the comparison of the two regimes: If the government is budget-constrained, it may be possible that only under the non-benevolent government the first best is attainable. This is because the non-benevolent government has to pay less compensation than the benevolent one. The non-benevolent government's advantage is that it can credibly commit to take the property whenever due compensation is lower than project's value, whereas the benevolent government takes the property only when it is ex post socially desirable.

Chapter II also uses a machinery which is different from previous approaches, such as in Che and Chung (1999).[5] The mapping from investments into realized values does not need to be differentiable. Furthermore, in settings of bilateral investment, this technique allows much more elegant proofs because one does not need to calculate with the help of integrals.

Breakdown in Multilateral Bargaining

Having completed the paper about the economic analysis of compensation for takings, we thought that a natural extension was the justification for eminent domain. The common justification cited by other papers such as Miceli and Segerson (2007a) and Shavell (2010) is the "hold-out"

[5] This technique is also used in Schweizer (2006) and Göller (2011).

problem. According to them, the problem could emerge if public authorities had to buy adjacent blocks of land. Landowners would delay their purchase and wait to be the last one to sell their land to the government in order to get a large part of the surplus.

However, this argument is still in its infancy. The papers only consider one specific model with two periods. Although the problem is isomorphic to any situation in which one central party wants to buy perfect complements from different sellers, there is only very few connections to such models, as Cai (2000), Cai (2003), and Menezes and Pitchford (2004). We thought that these models could show us a model which yielded a breakdown or at least some delay. But, very soon, we alighted on the following quote:

> *"Multiplicity of equilibria unfortunately makes the models lose predictive power. This is especially problematic for the bargaining literature, because usually there is a continuum of equilibrium outcomes in bargaining models that do not have a unique equilibrium. [...]However, when a complete information model has a unique stationary or Markov equilibrium, it must be efficient."*
>
> —*Hongbin Cai*

At first glance, this is a disappointing finding. In an applied paper, it is difficult to make the case for a rule if even without the rule the first best is attainable. Referees and editors in a law and economics journal would rather not buy a model in which the purpose of an institution is to destroy inefficient equilibria. Time to start from scratch.

At that point, we decided to forget about things like Markov perfect equilibria and stationarity for a moment. Besides the obviously correct strategic delay problem there was still another aspect: If some sellers refuse to sell their property, the buyer has spent large amounts without receiving anything. Think of an airport: If it has managed to acquire only some of the parcels that it needs for a new runway, it won't certainly start to feed the pigs. In other words, the airport may have a lower stand-alone valuation than the sellers.

We considered a simple numerical example and figured out that later sellers might be able to extract more than the ex ante pie. If this is the case, a breakdown in negotiations occurs as the unique equilibrium outcome. In order to establish this result, we do not need any refinements such as Markov perfect equilibria or stationarity. Finally, we were able to show that there are situations in which negotiations would lead to inefficient outcomes.

This was an important step for our research. So far, not a single paper examines the impact of a situation in which the buyer had a lower stand-alone valuation than the seller. Previous papers on multilateral bargaining make implicitly a simplifying assumption: They assume that the central party is able to derive the same stand-alone utility as the sellers. We agreed that this was only an innocent assumption if either only one farmer was involved or if the airport was able to derive the same stand-alone utility from the goods as the farmers, which needs not to be true.

This is what got us really started. Because the driving force behind the breakdown result does not depend on a specific structure, we decided to consider a large class of games instead of a specific game. The finding is that in every game breakdown occurs with certainty for some parameter constellations. This result holds even without any refinement criteria. Compared to previous work in bargaining theory, this is a very strong result. Other papers find that results depend heavily on the assumed bargaining structure.

If the last farmer to sell his property has a non-negative bargaining power, his share may be larger than the net social surplus. If this is the case, the coalition of the first farmer and the airport cannot make positive profits. Hence, they will never agree on a land purchase. A similar logic applies if the airport makes simultaneous offers to the farmers. For the farmers to accept immediately such an offer both need to receive at least the payoff they would get in bilateral bargaining. The sum of these payoffs may well be greater than what the airport is willing to pay.

The two-seller case contains most of this chapter's innovation. Nevertheless, we also study the impact of the number of farmers. So, chapter

III takes a specific bargaining procedure that was particularly easy to solve: A fixed ordering of the farmers is taken as given. The airport plays a standard alternating-offers game with each of the farmers. Only if it has reached an agreement with one of the farmers, it is allowed to move to the next one. The big advantage of this bargaining procedure is that it has only one subgame perfect equilibrium. Cai (2000) assumes a slightly different procedure. Nevertheless, he is not able to derive all the equilibria of the game. For any given parameter constellation a breakdown occurs if the number of farmers is sufficiently large. With the growing number of farmers the project size and the total value of the land that is necessary are held constant. Again, this is an interesting result because for any given project size and social surplus breakdown can occur.

After the literature had been looking for inefficiencies in multilateral bargaining for years, chapter III is able to make an interesting point. An interesting extension could be to enlarge the contract space and allow for contracts that are contingent on later agreements between the airport and other farmers. But, nevertheless, the model finds a very intuitive explanation for a frequently observed phenomenon in real life: The fact that negotiations between several parties often involve inefficiencies.

Of course, this insight is not limited to the justification for eminent domain. It can also be applied to the economic analysis of bankruptcy law or takeovers of a corporation. At this point, we can see a connection to the first chapter.

Chapter III offers an explanation for bargaining inefficiencies. While the impact of more complex contracts is not clear at first glance, the bargaining inefficiencies would certainly not exist if all involved parties could write a complete contract. Hence, also chapter III models a world of incomplete contracts.

I. Information and Priority Rules

Bankruptcy and corporate laws in several countries allow or require courts to subordinate loans by shareholders to corporations. Examples include the equitable subordination and recharacterization doctrines in US and German law. Scholars have not devoted much attention to these rules so far despite their rather unclear economic implications. We propose a model that focuses on the role of information and ex ante investment incentives. We found that informational asymmetries can justify the requalification: The more priority is given to the uninformed creditor, the better are the results from a welfare perspective.

1. Introduction

In many legal systems, credits given by an owner of a significant amount of shares are fulfilled after the other creditors' claims in bankruptcy. In U.S. law, §510 bankruptcy code lays down that a claim can be subordinated by the court. This is the case when the creditor has acted inequitably[1] and harmed the debtor or the debtor's other creditors. The consequence is that the claim's priority is reduced, so that the other creditors' claims are fulfilled before. According to these rules, bankruptcy courts have the power to subordinate claims on any grounds recognized in equity (Feibelman (2007), pp. 172-173). The scope of the provisions is very broad. For instance, all kinds of insiders may have to suffer from the rule, i.e., "any person in control of the debtor".[2] However, superior information alone is not sufficient for the court to subordinate a loan. Other legal systems have similar rules.[3] Under German law, credits issued by large stockholders are automatically subordinated.[4] A subordination of claims by close persons is not possible.

Despite the high practical relevance of these provisions[5] and their rather unclear implications, economic analyses are surprisingly rare. The economic analysis of bankruptcy law mostly considers a firm that is already in financial distress and does not consider ex ante investment in-

[1]which refers to equity not as a term in finance, but rather to justice.

[2]cf. the definition in Bankruptcy Code §101 (31).

[3]For an overview, see Gelter (2006). In German law the credit given by an owner of at least one tenth of the shares is served after all other claims raised in the bankruptcy procedure (cf. §39 of the German bankruptcy code). The argument made by legal scholars is that the owner of a corporation should bear the consequences of the firm's financing and should not transfer the firm's risk to the creditors (Kirchhof, Lwowski, and Stürner (2008), §135, No. 1-4.). Until recently the requalification required that the loan was given in a crisis of the firm, i.e., in a situation where no third party would have given a credit to it. Under German law, only the claims of the owner of the firm can be subordinated. Claims of insiders or close persons cannot be subordinated, not even at the discretion of the court.

[4]Cf. §39 InsO (German Bankruptcy Code).

[5]Gelter (2006), Claussen (1996), p. 317, describes a massive increase in the number of cases since 1985.

centives.[6]

Gelter (2006) examines a moral-hazard related justification for the equitable subordination doctrine: After a creditor has issued a credit, the owner or a close person grants another credit, which decreases the first creditor's claims in bankruptcy. Obviously, one of the legislator's motives in such a situation would be to react to this externality and to deter socially undesirable credits by the owner or close person. However, Gelter shows that if the liquidation value before the second credit is lower than the first creditor's claim, the rule may also deter socially desirable investments. Furthermore, the equitable subordination doctrine would not solve these problems: As long as there are no informational asymmetries, the creditor could also demand a loan from an outside creditor to which the doctrine cannot be applied.

Therefore, we focus on the role of informational asymmetries. We analyze how this can lead to inefficient outcomes and how these outcomes are influenced by bankruptcy rules. We consider a model related to Bolton and Scharfstein (1990), where an entrepreneur wants to conduct a project that randomly yields either a low or a high cash flow. The probability of success denotes the entrepreneur's type. The project is only started if it is financed by two creditors. Only one of the creditors is able to observe the entrepreneur's type. As an example, consider a relationship bank with limited lending capacity which can observe the true success probability of the project. We compare different priority rules with respect to their welfare implications.

We find that, generally, too many projects are realized. The main result is that the more priority is given to the uninformed creditor, the less are the overinvestment incentives and the better are the results from a welfare perspective. Let us consider two extreme cases: If the un-

[6]Commonly studied topics include under which conditions a firm should be reorganized or liquidated and how managers' incentives are (Posner (1977), pp. 544-511), whether contracts can substitute the mandatory bankruptcy procedure (White (2007), pp. 1038-1040), whether the current state of law promotes efficient incentives (White (1989)) or how the pie should be distributed in case of bankruptcy in order to reach fairness and efficiency (Bebchuk (1988)).

informed creditor's claim has priority and if even the low cash flow is sufficient to repay it, she bears no default risk. Then, the informed creditor bears the whole loss risk and therefore grants a loan if and only if it is socially profitable. At the other extreme, under informed creditor's priority, if even the low cash flow is sufficient to repay the claim, she accepts the offer by the entrepreneur independent of his type. Then, either all or none of the projects will be financed, depending on whether all projects on average are socially profitable. This would also be the case if both creditors were uninformed. Consequently, from a social viewpoint, the creditor's information is lost. Equity financing performs rather poorly in our setting because the informed party receives relatively much in the bad state of the world. Accordingly, informational asymmetries can provide an additional justification for the equitable subordination doctrine. Hence, claims of parties with superior information about the entrepreneur's characteristics should be subordinated in bankruptcy.

Our result is related to the pecking-order hypothesis[7], according to which firms prefer to issue secure claims in an asymmetric information framework. Moreover, the results are related to papers that emphasize the value of collaterals in credit markets with imperfect information.[8] However, none of these models considers the interplay between an entrepreneur and two types of creditors. Also related are papers in which there is no ex ante type uncertainty, but creditors try to avoid ex post opportunistic behavior by the entrepreneur, e.g., with the help of a threat to liquidate the entrepreneur's assets. Bebchuk and Fried (1996) and Berglöf and von Thadden (1994) consider the interplay of several creditors. Other papers include Bizer and DeMarzo (1992), Bester (1994) and Hart and Moore (1998). Bebchuk (2002) examines a trade-off between incentives to efficient project choice and ex post efficient continuation. Bolton and Scharfstein (1996) endogenize the number of creditors in such a setting.

[7]Tirole (2006), pp. 246-249 and Myers (1984).

[8]Stiglitz and Weiss (1981), Bester (1985) and Bester (1987).

Concluding that subordination is beneficial, one could make a case for why it should be mandatory law. Gelter (2006) addresses these concerns, but does not find a solution to this.

In the relationship between several creditors such an ordering will usually be difficult in the absence of collaterals.[9] Credit safeguarding may not always be possible.[10] Debt contracts are only valid between the parties and other stakeholders have no possibility to observe whether a certain agreement has been made. Furthermore, agreements between the owner and one of the creditors about the priority of third-party claims are void. Scholars see the large amount of creditors and different preferences about the bankruptcy procedure as an obstacle to contract about the procedure.[11] For instance, the content of future contracts is difficult to oversee.[12] These arguments often refer to the choice of the bankruptcy procedure[13], but can also explain why priority agreements between different creditors may not be possible.

By contrast, priority agreements between the owner and a creditor are binding. However,the entrepreneur may ex post be able to convert his contribution to debt (hidden action). In most legal systems, the amount of equity is observable in the commercial register and if equity is lowered, the creditor can request back his loan.[14] However, monitoring the entrepreneur's behavior or changes of the commercial register may be too costly. This is especially plausible when there is a large number of creditors with little stakes. Bebchuk and Fried (1996) call those "nonadjusting

[9]Collaterals are commonly used in order to reach priority agreements. As many forms of collaterals must be registered in a publicly observable register, they are also valid in the relationship between several creditors.

[10]Either we may have assets with high sunk costs, where the value for potential buyers is close to zero. Then the enforcement of these collaterals will not be worthwhile for the creditor. Or we have assets that cannot serve as a security at all, because of legal (e.g., the entrepreneur's idea is not protected as a patent) or economic reasons (if the value of the idea or the patent is stochastic and its value is highly positively correlated with the entrepreneur's success).

[11]Schwartz (1997), p. 128.

[12]Aghion, Hart, and Moore (1992), pp. 6-7.

[13]White (2007), p. 1040.

[14]For German law, cf. §§58 GmbHG(Limited Act), 225 AktG (Stock Company Act).

creditors". Furthermore, the owners could secretly lower their equity by buying assets from themselves at unreasonably high prices. Hence, there may be moral-hazard behavior by the entrepreneur that might prevent the parties from reaching the desired outcome by contract.

The chapter is organized as follows: In section 2, we present the model without describing the informational structure. In section 3, we consider the full information case as a benchmark. Section 4 investigates the asymmetric information case and compares the different bankruptcy rules and equity financing with respect to their welfare implications. Section 5 concludes.

2. The Model

We consider a model with three risk-neutral parties, an entrepreneur E, also referred to as "he", and two creditors U, I, both referred to as "she".[15] The entrepreneur has no financial means himself and needs financing from both creditors to start a project which may be efficient or inefficient. The creditors' contributions are fixed and amount to d_U and d_I, respectively. We denote the sum of the contributions as $D := d_U + d_I$. W.l.o.g. we normalize $D = 1$. Once the project is started, it can either generate a low cash flow $Y_L < D$ or a high cash flow $Y_H > D$. The probability of the high cash flow is given by $q \in [0, 1]$ and is different between the entrepreneurs. Hence, q denotes the entrepreneur's type. For simplicity, let us assume that the parties do not discount between financing and the realization of the cash flows, or, in other words, that the riskless interest rate is equal to zero.

In the social optimum, all projects with positive expected net cash flow are realized. This is the case if and only if:

$$qY_H + (1-q)Y_L \geq D \Leftrightarrow q \geq \frac{D - Y_L}{Y_H - Y_L} =: q^{SO},$$

where q^{SO} denotes the socially optimal threshold.

[15]In the asymmetric information case U means "uninformed" and I "informed".

After q is chosen by nature according to a uniform distribution on $[0,1]$, the entrepreneur offers a credit contract r_U to creditor U in a take-it-or-leave-it fashion, where r_U is E's repayment obligation. The repayment obligation is non-contingent in the sense that it cannot condition on the ex post realized state of the world, which may either be Y_H or Y_L. The $U-$creditor's decision is denoted $z_U \in \{0,1\}$, where $z_U = 1$ means that she accepts the offer. After U's decision, the entrepreneur moves to the next creditor I. E proposes her a non-contingent repayment obligation in a take-it-or-leave-it fashion, too, which is denoted r_I. I's decision is denoted $z_I \in \{0,1\}$. At this point, we do not yet say anything about the informational structure.

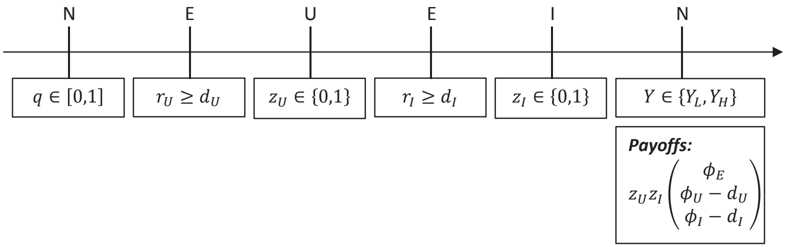

Figure I.1.: Timeline of the model

If at least one of the creditors refuses the entrepreneur's offer, the payoffs are zero for all parties. Hence, the payoffs for three parties E, U, I are given by $z_U \cdot z_I \cdot (\phi_E, \phi_U - d_U, \phi_I - d_I)$, where $\phi := (\phi_E, \phi_U, \phi_I)$ denotes the payments the three parties receive if the project is carried out. For convenience, let us assume that even if at least one of the creditors rejects the offer, nature determines the state of the world and that ϕ takes the values as defined in the next paragraph.

If both creditors accept the offer, the project is started and nature determines whether the high cash flow Y_H or the low cash flow Y_L occurs, where the high cash flow is realized with probability q. If the project is carried out and if the cash flow Y is sufficient to serve the creditors' claims ($r_U + r_I \leq Y$), the payments are determined by the contractual agreements, which implies $\phi = (Y - r_U - r_I, r_U, r_I)$. If the claims exceed the cash flow ($r_U + r_I > Y$), the bankruptcy rule determines the payments. Note that this is always the case when Y_L is realized, but may also occur in the good state of the world. In bankruptcy, the entrepreneur receives nothing ($\phi_E = 0$). We assume that the bankruptcy procedure is free of costs, $\phi_U + \phi_I = Y$. We consider three different bankruptcy rules: Under (i) U's and (ii) I's priority U's and I's claims are fulfilled first, respectively. Under (iii) the pro-rata rule, the bankruptcy payment is proportional to the credit initially invested. Formally, the rule in place α is defined as:

Priority of U (α_U): $\phi_U = \min[Y, r_U]$, and $\phi_I = Y - \phi_U$

Priority of I (α_I): $\phi_U = Y - \phi_I$, and $\phi_I = \min[Y, r_I]$

Pro-Rata Rule (α_P):

$$(\phi_U, \phi_I) = \begin{cases} (d_U Y, d_I Y) & \text{if} \quad r_U \geq d_U Y \text{ and } r_I \geq d_I Y \\ (Y - r_I, r_I) & \text{if} \quad r_U \geq d_U Y \text{ and } r_I < d_I Y \\ (r_U, Y - r_U) & \text{if} \quad r_U < d_U Y \text{ and } r_I \geq d_I Y. \end{cases}$$

Under the pro-rata rule, if both claims are sufficiently high, each of the creditors receives the share of the cash flow proportional to her credit (see the first line). If the repayment claim of one creditor falls short of this share, this creditor gets her repayment claim and the other party the remainder. This essentially excludes that one party may profit from bankruptcy. Note that if both repayment claims fall short of the share proportional to the credit, we have $r_I + r_U < Y$ and, consequently, there is no bankruptcy. In the following, we compare the bankruptcy rules with respect to their welfare implications.

3. The Full Information Case

As a benchmark, let us consider the full information case, in which both creditors can observe the true value of q and the full history of the game. As we have proper subgames, we use the concept of the subgame perfect Nash equilibrium (SPNE). We can solve this game by backwards induction. Let us fix any r_U, r_I and any z_U and observe which is the equilibrium value of I's decision $z_I^*(\alpha, q, r_U, z_U)$.

If U has accepted the entrepreneur's offer ($z_U = 1$), the I-creditor accepts if she expects a (weakly) positive payoff:

$$z_I^*(\alpha, q, r_U, r_I, z_U = 1) = \begin{cases} 1 & \text{if} \quad E[\phi_I(\alpha, r_U, r_I, Y)|q] \geq d_I \\ 0 & \text{else,} \end{cases} \tag{I.1}$$

where $E[\phi_I(\alpha, r_U, r_I, Y)|q] = q\phi_I(\alpha, r_U, r_I, Y_H) + (1-q)\phi_I(\alpha, r_U, r_I, Y_L)$ is the expectation value of the payment to I given a (known) value of q. If $z_U = 0$, hence if the U-creditor has refused the entrepreneur's offer, I's decision is arbitrary because the payoffs are 0 for all parties independent of her action. Let us assume that then she employs action (I.1), too.

Anticipating this, the entrepreneur makes I an offer such that she exactly breaks even. Observe that under any rule, if bankruptcy occurs and if the payment to I in bankruptcy falls short of her repayment claim r_I, a further increase in r_I does not increase the payment she receives. Hence, $r_I^* = r_I^*(\alpha, q, r_U, z_U = 1)$ is implicitly given by

$$qr_I^* + (1-q)\phi_I(\alpha, r_U, r_I^*, Y_L) = d_I. \tag{I.2}$$

Note that this equation has a unique solution because ϕ_I is continuous and increasing in r_I^* and hence, the left-hand side is continuous and strictly increasing in r_I^*. The actions according to (I.1) and (I.2) are unique if U has accepted E's offer ($z_U = 1$) and $Y_H - r_U - r_I^* > 0$ holds because the entrepreneur could offer the $I-$creditor a tiny amount more and ensure himself and the $I-$creditor a strictly positive payoff. Of course the entrepreneur may offer anything if he anticipates that the offer is rejected anyway, if U has rejected the offer, or if $Y_H - r_U - r_I^* \leq 0$ holds. Then, his payoff is zero anyway. For the moment, let us assume that then I and E play the actions (I.1) and (I.2), too.

Ex ante, E and U anticipate $r_I^*(\alpha, q, r_U, z_U)$ and $z_I^*(\alpha, q, r_U, r_I^*, z_U)$. U accepts if and only if she expects to break even:

$$z_U^*(\alpha, q, r_U) = \begin{cases} 1 & \text{if} \quad z_I^* \cdot E[\phi_U(\alpha, r_U, r_I^*, Y) - d_U | q] \geq 0 \\ 0 & \text{else.} \end{cases} \tag{I.3}$$

Note that this expression is well-defined as neither r_I^* nor z_I^* are functions of z_U. Similar to r_I, $r_U^*(\alpha, q)$ is implicitly given by

$$qr_U^* + (1-q)\phi_U(r_U^*, r_I^*, Y_L) = d_U. \tag{I.4}$$

Note that (I.4) has a unique solution as ϕ_U is continuous and increasing in r_U^*.[16] Observe that whenever r_I^*, z_I^* are not unique in equilibrium, the entrepreneur's payoff is zero. Hence, if $r_U^* + r_I^*$ according to (I.2) and (I.4) is less than Y_H, the above actions are unique. Reorganizing yields:

$$\begin{aligned}
& r_U^* + r_I^* < Y_H \\
\Leftrightarrow & q(r_U^* + r_I^*) + (1-q)Y_L < qY_H + (1-q)Y_L \\
\Leftrightarrow & \overbrace{qr_U^* + (1-q)\phi_U(r_U^*, r_I^*, Y_L)}^{=d_U} + \overbrace{qr_I^* + (1-q)\phi_I(\alpha, r_U, r_I^*, Y_L)}^{=d_I} \\
& \qquad < qY_H + (1-q)Y_L \\
\Leftrightarrow & D < qY_H + (1-q)Y_L \\
\Leftrightarrow & q^{SO} < q.
\end{aligned}$$

Hence, all socially efficient projects are carried out in any equilibrium. For $q < q^{SO}$, $r_U^* + r_I^* < Y_H$ holds and, consequently, at least one of the creditors cannot break even. Only for q^{SO} the outcome is indeterminate. We can conclude that

Proposition I.1: *Under full information, independent of the bankruptcy rule, first best is the unique equilibrium outcome. In this sense, no ranking of the bankruptcy rules is possible.*

[16] Although $r_I^*(r_U)$ is weakly increasing in r_U, $\phi_I(\alpha, r_U, r_I^*(r_U), Y_L)$ cannot be increasing in r_U because then I's zero profit-condition (I.2) would be violated. Hence, $\phi_U(\alpha, r_U, r_I^*(r_U), Y_L) = Y_L - \phi_I(\alpha, r_U, r_I^*(r_U), Y_L)$ is increasing in r_U.

The intuition for this result is that if a project is efficient from a social perspective, the entrepreneur is able to make offers to both creditors such that they break even. This result is related to Buckley (1986), who shows that under perfect information the existence of collaterals does not have an impact on the firm's value - a result in the spirit of the theory of Modigliani and Miller (1958). The result is also quite intuitive as, under symmetric information, at least one of the creditors cannot break even when the project is socially not profitable, whereas both creditors can break even when this is the case.

4. The Asymmetric Information Case

In the last section, we found that no ranking between the bankruptcy rules is possible under full information. Now, we turn to the asymmetric information case, in which the $U-$ or uninformed creditor is not able to observe the true value of q. She only knows that q is uniformly distributed between 0 and 1. Because we consider a game with asymmetric information, we need to define U's beliefs: $\mu : r_U \to \mu(q, r_U)$ assigns densities to all possible values of q for a given information set r_U. We use the sequential equilibrium (Kreps and Wilson (1982)) as solution concept.

4.1. The One-Creditor Case

Before turning attention to the different rules, let us consider as another benchmark case $d_U = D, d_I = 0$, i.e., the case in which there is only the uninformed creditor. Then, there is no difference between the bankruptcy rules.

Given any offer r_U by the entrepreneur, the uninformed creditor has some belief about the entrepreneur's type. The creditor is able to calculate her expected payoff for any given entrepreneur type. Hence, for a

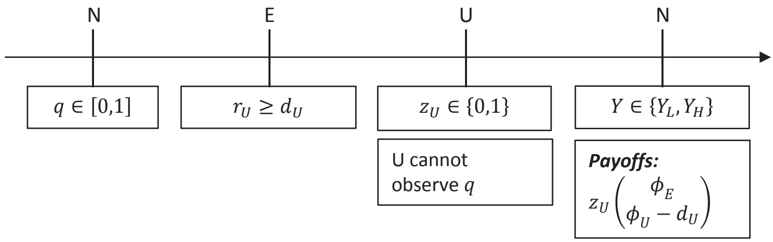

Figure I.2.: Timeline: One creditor with asymmetric information

given r_U, her expected payoff is given by

$$\int_0^1 \mu(q, r_U) E[\phi_U(r_U, Y) - D|q] \,\mathrm{d}\, q.$$

She has a strict incentive to accept any offer that gives her a positive payoff in expectation and to reject any offer that yields her a strictly negative payoff. For convenience, let us assume that she accepts also any offer that yields her zero payoff:

$$z_U^*(r_U) = \begin{cases} 1 & \text{if} \quad \int_0^1 \mu(q, r_U) E[\phi_U(r_U, Y) - D|q] \,\mathrm{d}\, q \geq 0 \\ 0 & \text{else.} \end{cases}$$

Note that this holds both for values on and off the equilibrium path, where the expectation on the equilibrium path is derived with the help of Bayes' rule. The entrepreneur wants to minimize the creditor's repayment claim under the condition that she accepts the offer.[17] Formally, this can be written as:

$$r_U^*(q) \in \arg\max \frac{z_U^*(r_U)}{r_U}. \tag{I.5}$$

Note that if there is no value of r_U such that U breaks even, she rejects any offer, and, consequently, the entrepreneur's payoff is zero independent of his offer. As a direct corollary from (I.5), we can focus on equilibria in which all entrepreneur types offer the same r_U, which is different

[17]Note that this action is not unique if all offers r_U that are accepted by the uninformed creditor exceed Y_H. But still, this value is part of a reasonable equilibrium.

to the well-known signaling framework in Cho and Kreps (1987). This is because there is no signal but the offer to the uninformed creditor. As all entrepreneurs want to minimize their payment to the creditor, they all choose the same r_U.

Now, we know what happens in the game for a given belief system $\mu(q, r_U)$. Furthermore, we know that on the equilibrium path, the belief system is determined with the help of Bayes' rule. However, for any offer $r_U \neq r_U^*$ off the equilibrium path, the creditor may assign arbitrarily low values of q and consequently, think that she does not break even. Hence, any level of r_U can be an equilibrium offer by the entrepreneur. However, taking into account that the entrepreneur makes the uninformed creditor a take-it-or-leave-it offer, it is safe to consider those equilibria in which the creditor makes exactly zero profit.[18] Therefore, let us assume that, in any equilibrium, the uninformed creditor assigns the same probability to all types given that a deviation has been observed. This assumption can be justified with the fact that all entrepreneur types offer the same r_U in equilibrium. With this refinement criterion, U's believed payoff for any offer off the equilibrium path $r_U \neq r_U^*$ is given by $\int_0^1 \mu(q, r_U) E[\phi_U(r_U, Y) - D|q] \, \mathrm{d}\, q$, which is equal to her payoff if this r_U was offered by all types. Hence, the entrepreneur sets r_U such that she makes exactly zero profits. We establish

Proposition I.2: *In the one-creditor asymmetric information case, the following sequential equilibrium exists:*

$$\textbf{\textit{E:}}\ r_U^* = 2D - Y_L$$

$$\textbf{\textit{U:}}\ z_U^* = \begin{cases} 1 & \textit{if} \quad \int_0^1 \mu(q, r_U) E[\phi_U(r_U, Y) - D|q] \, \mathrm{d}\, q \\ 0 & \textit{else.} \end{cases}$$

The creditor's beliefs are $\mu(q, r_U) = 1, \forall q \in [0,1], \forall r_U \geq d_U$.

In this equilibrium, either all or none of the projects get started.

[18]E.g. Tirole (2006), p. 242-244 implicitly assumes the same.

Proof. U's zero profit condition yields $\int_0^1 q r_U^* + (1-q)Y_L \,\mathrm{d}\, q = D$ and is solved by $r_U^* = 2D - Y_L$.

The beliefs are consistent: On the equilibrium path, all types offer r_U^*, from which the above distribution follows. For off-equilibrium path beliefs, consider the following trembling function that assigns probabilities to any r_U off the equilibrium path: $r_U \to \epsilon f(r_U)$, where $f(r_U)$ is a density function with $f(r_U) > 0, \forall r_U$ and $\int_{d_U}^{\infty} f(r_U)\mathrm{d}r_U = 1$, and $\epsilon < 1$ is a number that converges to zero. The density value for any q given a deviation $r_U \neq r_U^*$ has been observed is: $\frac{\epsilon f(r_U)}{\epsilon f(r_U) \int_0^1 1\mathrm{d}q} = 1$, where $\int_0^1 1\mathrm{d}q$ is the (uniform) distribution of q on $[0,1]$.

Note that if the projects are not profitable on average ($\int_0^1 qY_H + (1 - q)Y_L \,\mathrm{d}\, q < D$), the entrepreneur cannot make an offer such that U breaks even. If they are profitable ($\int_0^1 qY_H + (1-q)Y_L \,\mathrm{d}\, q \geq D$), all projects are realized. ■

The result in proposition (I.2) is of course inefficient. In the next sections, we will examine how the share d_I of the informed creditor can be used in order to achieve a better result from a welfare perspective.

4.2. The Two-Creditors Case

Now, we come to the main and most interesting part of the chapter. Here, we again consider a situation with two creditors, U and I. Here, U is the uninformed and I the informed creditor. U is not able to observe the true entrepreneur's type q. By contrast, I observes the true value of q and the full history of the game.

Let us proceed as follows: We analyze each of the cases separately and compare the welfare implications afterwards. As the equilibrium outcomes are not unique for most of the cases, we select for each case a reasonable equilibrium that fulfills some properties such as the restriction on off-equilibrium path beliefs already employed in the one-creditor case.

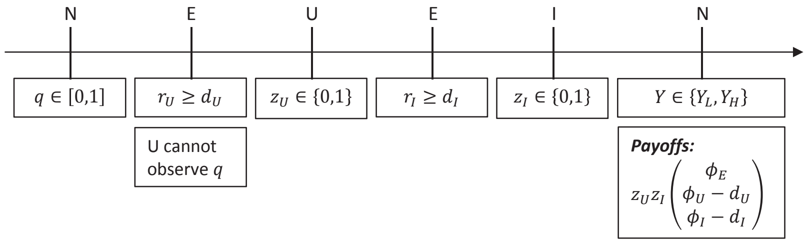

Figure I.3.: Timeline: Two creditors with asymmetric information

4.3. Uninformed Creditor's Priority

To begin with, consider uninformed creditor's priority. As the informed creditor is the residual claimant of the firm's cash flow, this case resembles to her holding equity. For purposes of the analysis, let us distinguish between two cases: In the first one, $d_U \leq Y_L$ holds, i.e., even the low cash flow is sufficient to pay back U's loan. In the second one ($d_U > Y_L$), U's repayment claim exceeds her credit d_U.

Uninformed Creditor's Priority with $d_U \leq Y_L$

As any sequential equilibrium is subgame perfect, the informed creditor accepts any offer that makes her break even, and, anticipating this, the entrepreneur sets $r_I^* = r_I^*(\alpha_U, q, r_U, z_U)$ such that she exactly breaks even

$$z_I^*(\alpha_U, q, r_U, r_I, z_U) = \begin{cases} 1 & \text{if} \quad E[\phi_I(\alpha_U, r_U, r_I, Y)|q] \geq d_I \\ 0 & \text{else} \end{cases} \tag{I.1}$$

$$qr_I^* + (1-q)\phi_I(r_U, r_I^*, Y_L) = d_I, \tag{I.2}$$

like in the full information case. Again, the actions (I.1) and (I.2) are unique if U has accepted E's offer ($z_U = 1$) and if $Y_H - r_U - r_I^* > 0$ holds because then the entrepreneur could offer the $I-$creditor a tiny amount more and ensure himself and the $I-$creditor a strictly positive payoff. Of course the entrepreneur may offer any amount if he anticipates that his offer is rejected anyway, if U has rejected the offer, or if $Y_H - r_U - r_I^* \leq 0$ holds. In this case his payoff is zero anyway.

Because of $d_U \leq Y_L$, the uninformed creditor gets at least her credit back independent of which state of the world occurs. Hence, in equilibrium, the entrepreneur offers the least value of r_U such that the uninformed creditor breaks even, which she accepts:

$$z_U^*(\alpha_U, r_U) = \begin{cases} 1 & \text{if} \quad r_U \geq d_U \\ 0 & \text{else} \end{cases}$$
$$r_U^*(\alpha_U, q) = d_U.$$

Note that the above actions are even unique if $Y_H - r_U^* - r_I^*(\alpha_U, q, r_U, z_U) > 0$ holds. Observing that $\phi_I(\alpha_U, r_U^*, r_I^*, Y_L) = Y_L - d_U$, we can reorganize:

$$Y_H - r_U^* - r_I^* > 0 \Leftrightarrow Y_H > d_U + \frac{d_I - (1-q)(Y_L - d_U)}{q}$$
$$qY_H + (1-q)Y_L > D \Leftrightarrow q > q^{SO}.$$

Hence, in any equilibrium, all strictly efficient projects are realized. For strictly inefficient projects, the informed creditor cannot break even, which means that these projects are not carried out. Only for $q = q^{SO}$ the outcome is indeterminate. We can conclude that

Proposition I.3: *Under uninformed creditor's priority and when even the low cash flow is sufficient to pay back U's loan ($d_U \leq Y_L$), first best is the unique equilibrium outcome.*

Intuitively, the uninformed creditor's claim is fulfilled in any state of the world, which means that she does not suffer from the financing of inefficient projects.

Uninformed Creditor's Priority with $d_U > Y_L$

Now, let us consider the case, in which the low cash flow is not sufficient to repay U's claim. Here we are no longer able to derive a unique equilibrium outcome. Note that the informed creditor receives nothing in bankruptcy as $r_U \geq d_U > Y_L$ holds. Given any r_U, z_U, E and I play the following actions:

$$z_I^*(\alpha_U, q, r_U, r_I, z_U) = \begin{cases} 1 & \text{if} \quad E[\phi_I(\alpha_U, r_U, r_I, Y)|q] \geq d_I \\ 0 & \text{else} \end{cases} \tag{I.6}$$

$$qr_I^* + (1-q)\underbrace{\phi_I(\alpha_U, r_U, r_I^*, Y_L)}_{=0} = d_I \Leftrightarrow r_I^*(\alpha_U, q, r_U, z_U) = \frac{d_I}{q}, \tag{I.7}$$

which can always be supported as an equilibrium and is even unique if the uninformed creditor has given a credit ($z_U = 1$) and if $Y_H - r_U - r_I^* > 0$ holds. If $Y_H - r_U - r_I^* \leq 0$ holds, the entrepreneur makes zero profits anyway. For convenience, let us assume that then I and E play (I.6) and (I.7), too.

Again, U anticipates the equilibrium values r_I^*, z_I^*. In any equilibrium, she accepts any offer that promises her a strictly positive payoff and rejects any offer if she expects a strictly negative payoff. As before, let us assume that she also accepts when her expected payoff is zero:

$$z_U^*(\alpha_U, r_U) = \begin{cases} 1 & \text{if} \quad \int_0^1 \mu(q, r_U) \cdot z_I^* \cdot E[\phi_U(\alpha_U, r_U, r_I^*, Y) - d_U|q] \,\mathrm{d}\, q \geq 0 \\ 0 & \text{else.} \end{cases}$$

Note that neither r_I^* nor z_I^* are functions of z_U, which means that the expression for z_U^* is well-defined. The entrepreneur maximizes $\max[Y_H - r_U^* - r_I^*, 0]$. Observing that r_I^* does not depend on r_U, we can conclude that E chooses the lowest value of r_U that is accepted by U. If she rejects any offer, the entrepreneur is of course indifferent between the offers:

$$r_U^*(\alpha_U, q) \in \arg\max \frac{z_U^*(\alpha_U, r_U)}{r_U}, \tag{I.8}$$

which can even be supported as an equilibrium if $Y_H - r_U^* - r_I^* \leq 0$ holds. Given (I.8), there is a threshold, above which all and below which no project is financed by the informed creditor. Let us denote this threshold for given r_U as $q_L(\alpha_U, r_U|d_U > Y_L)$. Observe that the informed creditor can break even if $d_I/q + r_U \leq Y_H$ holds. Hence, the threshold is given by:

$$q_L(\alpha_U, r_U | d_U > Y_L) = \frac{d_I}{Y_H - r_U}. \tag{I.9}$$

Unfortunately, any level of r_U can be supported as an equilibrium because the uninformed creditor may assign arbitrarily low values of q to any r_U off the equilibrium path. At this point, the argument made in the one-creditor case kicks in: If all entrepreneurs choose the same r_U, it is safe to assume that the uninformed creditor assigns the same probability to all types given that a deviation has been observed. Hence, for any r_U off the equilibrium path, U believes

$$\begin{aligned}&\int_{q_L}^{1} E[\phi_U(\alpha_U, r_U, r_I = \frac{d_I}{q}, Y) - d_U | q] \,\mathrm{d}\, q \\ &= E[\phi_U(\alpha_U, r_U, r_I = \frac{d_I}{q}, Y) - d_U | q \geq q_L]\end{aligned}$$

to be her payoff. Note that q_L is continuous and strictly increasing in r_U and r_U is continuous and strictly decreasing in q_L. Hence, in equilibrium, she makes exactly zero profit:

$$\begin{aligned}&E[\phi_U(\alpha_U, r_U, r_I^*, Y) - d_U | q \geq q_L(\alpha_U, r_U | d_U > Y_L)] = 0 \\ \Leftrightarrow & r_U = \frac{2d_U - (1 - q_L)\, Y_L}{1 + q_L}.\end{aligned} \tag{I.10}$$

Combining (I.9) and (I.10) yields the unique equilibrium threshold

$$\begin{aligned}q_L^*(\alpha_U | d_U > Y_L) = &-\frac{Y_H + Y_L - d_U - D}{2(Y_H - Y_L)} \\ &+ \frac{\sqrt{[Y_H + Y_L - d_U - D]^2 + 4d_I(Y_H - Y_L)}}{2(Y_H - Y_L)},\end{aligned} \tag{I.11}$$

as shown in appendix 1.1. The set of realized projects cannot be empty, because I accepts only if $r_I + r_U \leq Y_H$ holds, which ensures that U breaks even. Note that in this equilibrium E's offer r_I^* and I's answer z_I^* are unique for all $q > q_L^*(\alpha_U | d_U > Y_L)$.

To sum up, we can describe the equilibrium as follows:

Proposition I.4: *Under uninformed creditor's priority and $d_U > Y_L$, there exists the following sequential equilibrium:*

$$\textbf{\textit{E:}}\ r_U^* = \frac{d_U - [1 - q_L^*(\alpha_U|d_U > Y_L)]\, Y_L}{1 + q_L^*(\alpha_U|d_U > Y_L)}$$

$$\textbf{\textit{U:}}\ z_U^* = \begin{cases} 1 & \textit{if} \quad E[\phi_U(\alpha_U, r_U, r_I = \frac{d_I}{q}, Y) - d_U | q \geq \frac{d_I}{Y_H - r_U}] \geq 0 \\ 0 & \textit{else} \end{cases}$$

$$\textbf{\textit{E:}}\ r_I^* = \frac{d_I}{q}$$

$$\textbf{\textit{I:}}\ z_I^* = \begin{cases} 1 & \textit{if} \quad E[\phi_I(\alpha_U, r_U, r_I, Y)|q] \geq d_I \\ 0 & \textit{else.} \end{cases}$$

The uninformed creditor's beliefs are $\mu(q, r_U) = 1, \forall q \in [0,1], \forall r_U \geq d_U$.

In this equilibrium, all projects $q \in [q_L^*(\alpha_U|d_U > Y_L), 1]$ get started.

Observe that the beliefs are consistent (see the one-creditor case).

4.4. Pro-Rata Rule

Recall that under the pro-rata rule, if the repayment claims exceed the share of the cash flow proportional to the credits, each creditor gets this share. As the repayment claims must exceed the credits ($r_U \geq d_U, r_I \geq d_I$), it is clear that the creditors get $d_U Y_L, d_I Y_L$ in the bad state of the world. In equilibrium, given any r_U, z_U, the entrepreneur play according to the following actions that are equivalent to the full information case:

$$z_I^*(\alpha_P, q, r_U, r_I, z_U) = \begin{cases} 1 & \text{if} \quad E[\phi_I(\alpha_P, r_U, r_I, Y)|q] \geq d_I \\ 0 & \text{else} \end{cases} \tag{I.12}$$

$$q r_I^* + (1-q) \underbrace{\phi(\alpha_P, r_U, r_I, Y_L)}_{= d_I Y_L} = d_I$$

$$\Leftrightarrow r_I^*(\alpha_P, q, r_U, z_U) = \frac{d_I - (1-q) d_I Y_L}{q}. \tag{I.13}$$

These actions can always be supported as an equilibrium and are even unique if the uninformed creditor has given a credit ($z_U = 1$) and if

$Y_H - r_U - r_I^* > 0$ holds. Recall that r_I^* solves I's zero-profit condition if she receives indeed r_I^* in the good state of the world. If the payment $\phi_I(\alpha_P, r_U, r_I^*, Y_H)$ falls short of r_I^*, which may occur in bankruptcy, a further increase in r_I does not increase her payoff, in which case she cannot break even.

Again, we assume that the uninformed creditor accepts any offer that yields her at least zero profit:

$$z_U^*(\alpha_P, r_U) = \begin{cases} 1 & \text{if} \quad \int_0^1 \mu(q, r_U) \cdot z_I^* \cdot E[\phi_U(\alpha_P, r_U, r_I^*, Y) - d_U | q] \, \mathrm{d}\, q \geq 0 \\ 0 & \text{else.} \end{cases}$$

Note that this expression is well-defined as neither r_I^* (see (I.13)) nor z_I^* (see (I.12)) are functions of z_U. As r_I^* does not depend on r_U, the entrepreneur offers the least value of r_U that is accepted by U:

$$r_U^*(\alpha_P, q) \in \arg\max \frac{z_U^*(\alpha_P, r_U)}{r_U}, \tag{I.8}$$

which can even be supported as an equilibrium if $Y_H - r_U^* - r_I^* \leq 0$ holds. Given that all entrepreneurs offer the same r_U, there is again a threshold above which the informed creditor finances all and below which she finances no project. Note that in the good state, the informed creditor can ensure herself a payment of $d_I Y_H$. Hence, she can finance all projects $q \geq q^{SO}$ independent of r_U. Additionally, she can finance all projects for which $r_U + r_I^* \leq Y_H$ holds. Hence, the threshold is given by

$$q_L(\alpha_P, r_U) = \min\left[q^{SO}, \frac{d_I(1 - Y_L)}{\max(Y_H - r_U, d_I) - d_I Y_L} \right], \tag{I.14}$$

where max $-$function prevents that the second argument of the min $-$function exceeds 1. U's payoff is given by

$$E[\phi_U(\alpha_P, r_U, r_I^*, Y) - d_U | q \geq q_L(\alpha_P, r_U)].$$

Again, we employ the above refinement criterion which implies that U's perceived payoff off the equilibrium path belief is equal to her payoff if it was offered by all types. Observe that U's expected payoff is continuous and strictly increasing in q_L and that the threshold is continuous and weakly decreasing in r_U. Hence, U makes zero profit in equilibrium:

$$\int_{q_L(\alpha_P,r_U)}^{1} [qr_U^* - (1-q)\overbrace{(\alpha_P, r_U, r_I^*, Y_L)}^{=d_U Y_L}] = 0$$

$$\Leftrightarrow r_U^* = \frac{2d_U - [1 - q_L(\alpha_P, r_U)]\, d_U Y_L}{1 + q_L(\alpha_P, r_U)}. \tag{I.15}$$

Combining (I.14) and (I.15) yields the unique equilibrium threshold

$$q_L^*(\alpha_P) = -\frac{Y_H - 2d_U + Y_L d_U - d_I}{2(Y_H - Y_L)} + \sqrt{\left[\frac{Y_H - 2d_U + Y_L d_U - d_I}{2(Y_H - Y_L)}\right]^2 + \frac{d_I - d_I Y_L}{Y_H - Y_L}}, \tag{I.16}$$

as shown in appendix 1.2. In equilibrium, U must break even, because I accepts on the equilibrium path if $r_I^* + r_U^* \leq Y_H$ holds. Hence, the set of realized projects is nonempty and the actions according to (I.12) and (I.13) are unique for all $q > q_L^*(\alpha_P)$. We establish:

Proposition I.5: *Under the pro-rata rule, there is the following sequential equilibrium:*

E: $r_U^* = \dfrac{2d_U - [1 - q_L^*(\alpha_P)]\, d_U Y_L}{1 + q_L^*(\alpha_P)}$

U: $z_U^* = \begin{cases} 1 & \text{if} \quad E[\phi_U(\alpha_P, r_U, \frac{d_I - (1-q)d_I Y_L}{q}, Y) - d_U | q \geq q_L(\alpha_P, r_U)] \geq 0 \\ 0 & \text{else} \end{cases}$

E: $r_I^* = \dfrac{d_I - (1-q)d_I Y_L}{q}$

I: $z_I^* = \begin{cases} 1 & \text{if} \quad E[\phi_I(\alpha_P, r_U, r_I, Y)|q] \geq d_I \\ 0 & \text{else.} \end{cases}$

The uninformed creditor's beliefs are $\mu(q, r_U) = 1, \forall q \in [0,1], \forall r_U \geq d_U$.

In this equilibrium, all projects $q \in [q^*(\alpha_P), 1]$ *are realized.*

4.5. Informed Creditor's Priority

If the informed creditor is served first in bankruptcy, she receives $\min(Y, r_I)$. Note that I's payoff does not depend on r_U. Again, the entrepreneur makes the informed creditor an offer such that she exactly breaks even, which she accepts:

$$z_I^*(\alpha_I, q, r_U, r_I, z_U) = \begin{cases} 1 & \text{if} \quad E[\phi_I(\alpha_I, r_U, r_I, Y)|q] \geq d_I \\ 0 & \text{else} \end{cases} \tag{I.17}$$

$$r_I^*(\alpha_I, q, r_U, z_U) = \frac{d_I - (1-q)\min[d_I, Y_L]}{q}, \tag{I.18}$$

which can always be supported as an equilibrium and is even unique if the uninformed creditor has given a credit ($z_U = 1$) and if $Y_H - r_U - r_I^* > 0$ holds. As I's payoff does not depend on r_U, we can directly infer the equilibrium threshold. She finances all projects with $qY_H + (1-q)Y_L \geq d_I$, which means:

$$q_L^*(\alpha_I) = \max\left[\frac{d_I - Y_L}{Y_H - Y_L}, 0\right].$$

If $d_I \leq Y_L$ holds, I bears no default risk, and hence, $r_I^* = d_I$ holds in equilibrium. In this case, I finances all projects. If her credit exceeds the cash flow in the bad state ($d_I > Y_L$), she funds the project if the expected cash flow is greater than her credit.

Again, in equilibrium, let us assume that the uninformed creditor accepts whenever she expects at least zero profit and that E chooses the lowest value of r_U which is accepted by her:

$$z_U^*(\alpha_I, r_U) = \begin{cases} 1 & \text{if} \quad E[\phi_U(\alpha_I, r_U, r_I^*, Y) - d_U | q \geq q_L^*(\alpha_I)] \geq 0 \\ 0 & \text{else} \end{cases}$$

$$r_U^*(\alpha_I, q) \in \arg\max \frac{z_U^*(\alpha_I, r_U)}{r_U}. \tag{I.8}$$

Note that the expression for $z_U^*(\alpha_I, r_U)$ is well-defined as neither r_I^* nor $q_L^*(\alpha_I)$ depend on z_U. Again, (I.8) can even be supported as an equilibrium if $Y_H - r_U^* - r_I^* \leq 0$ holds. If the projects for which I grants a credit ($q \in [q_L^*(\alpha_I), 1]$) are not profitable on average, there is no offer that U accepts in equilibrium because she makes a loss in expectation. If these projects are, by contrast, profitable on average, she may break even. Although the set of realized projects does not depend on how much profit the uninformed creditor makes, for convenience, let us again choose the value of r_U that leads to zero profit for the uninformed creditor. If $d_I \leq Y_L$ holds, the explicit solution for r_U^* is quite simple:

$$\int_0^1 q r_U^* + (1-q)(Y_L - d_I)\,\mathrm{d}\,q = d_U \Leftrightarrow r_U^* = 2d_U + d_I - Y_L.$$

Note that in this case, all entrepreneur types make a strictly positive profit in expectation, which implies that r_I^* and z_I^* are unique given the entrepreneur's offer to the uninformed creditor and her answer. By contrast, if the low cash flow is not sufficient to pay back I's loan in full, the solution for r_U^* is difficult to calculate because bankruptcy also occurs in the good state of the world for intermediate values of q.[19] We establish:

Proposition I.6: *Under informed creditor's priority, there is the following sequential equilibrium:*

E: $r_U^*(\alpha_I, q) \in \arg\max \dfrac{z_U^*(\alpha_I, r_U)}{r_U}$

U: $z_U^* = \begin{cases} 1 & \textit{if} \quad E[\phi_U(\alpha_I, r_U, \frac{d_I-(1-q)\min[d_I, Y_L]}{q}, Y) - d_U | q \geq q_L^*(\alpha_I)] \geq 0 \\ 0 & \textit{else} \end{cases}$

E: $r_I^* = \dfrac{d_I - (1-q)\min[d_I, Y_L]}{q}.$

I: $z_I^* = \begin{cases} 1 & \textit{if} \quad E[\phi_I(\alpha_I, r_U, r_I, Y)|q] \geq d_I \\ 0 & \textit{else.} \end{cases}$

The uninformed creditor's beliefs are $\mu(q, r_U) = 1, \forall q \in [0,1], \forall r_U \geq d_U$.

In equilibrium, either all $q \in [q^*(\alpha_I), 1]$ *or none of the projects are realized.*

[19] Note that in this case the actions according to (I.17) and (I.18) are not unique. However, in order to allow a comparison to the other cases, we assume that in that case, the projects are realized.

Note that if the informed creditor finances all projects, the result is the same as in the case of one uninformed creditor. Consequently, in this case, information on the market is lost.

4.6. Welfare comparison

Now, we are to compare the different rules with respect to their welfare properties. This is quite simple because welfare is only a function of the set of realized projects. Hence, we compare the cutoff-values for each of the rules and show that, generally, the equilibrium threshold $q_L^*(\alpha)$ is too low:

Proposition I.7: *If the set of realized projects is nonempty, then* $q_L^*(\alpha) \leq q^{SO}$*, i.e., too many projects are financed.*

Proof. See appendix 1.3. ■

Intuitively spoken, U receives d_U on average. However, the ex ante expected payment from low $q-$types to the uninformed creditor is generally lower than d_U. Hence, I can break even, although the project promises a negative net cash flow. The loss is borne by the uninformed creditor, who, in turn, receives a higher interest rate, which must be paid by all entrepreneurs. This indicates, too, that, compared to the full information case, there is a transfer of wealth from the good to the bad types.

Furthermore we can rank the bankruptcy rules with respect to their welfare properties:

Proposition I.8: *From a welfare perspective, the uninformed creditor's priority rule is best, followed by the pro-rata rule, which, in turn, outperforms informed creditor's priority.*

Proof. If no projects are realized under informed creditor's priority, welfare is equal to 0. In all other cases, welfare must be greater or bigger than 0 because if it was smaller than 0, at least one of the creditors could not break even. Welfare is given by $\int_{q_L^*(\alpha)}^1 [qY_H + (1-q)Y_L]\mathrm{d}q = \frac{1}{2}[(Y_H - Y_L) - q_L^*(\alpha)^2(Y_H - Y_L)] + (1 - q_L^*(\alpha))(Y_L - D)$ and is a symmetric and strictly concave function of the threshold $q_L^*(\alpha)$. Therefore the larger $\left| q_L^*(\alpha) - \frac{D-Y_L}{Y_H-Y_L} \right|$, the lower the welfare.

As in all cases $q_L^*(\alpha) \leq q^{SO}$, we know that the greater the threshold, the better the results from a welfare perspective. For the calculations, see appendix 1.4. ■

On intuitive grounds, the more priority U gets, the less important is the informational asymmetry and the less is I's incentive to finance socially inefficient projects. The same is true for the transfer of wealth: Under informed creditor's priority and $d_I \leq Y_L$, all types have the same credit contracts. At the other extreme, i.e., uninformed creditor's priority and $d_U \leq Y_L$, the outcome is equal to the full information case, which implies that there is no transfer at all. Hence, the inefficient use of information can justify the existence of the equitable subordination doctrine.

4.7. Performance of Equity Contracts

Finally, let us consider equity contracts as a benchmark. For instance, Jensen and Meckling (1976) argue that equity financing is best in asymmetric information frameworks.

Suppose I and U are not offered debt, but equity contracts, i.e., they receive a fixed share, denoted x_j, in any state of the world. This implies that the investors receive $x_U Y, x_I Y$ in either state of the world. Hence, bankruptcy cannot occur. We assume that U is guaranteed her share x_U: If $x_I + x_U > 1$ holds, the informed investor only gets a share of $1 - x_U$.[20] Let this case be denoted by α_E.

Given any x_U, z_U, E makes I an offer such that she exactly breaks

[20] If we had not this assumption, the result would be equal to that of I's priority, because for any x_U, x_I could be set such that I receives (nearly) everything.

even, which she accepts:

$$z_I^*(\alpha_E, q, x_U, x_I, z_U) = \begin{cases} 1 & \text{if} \quad E[\phi_I(\alpha_E, x_U, x_I, Y)|q] \geq d_I \\ 0 & \text{else} \end{cases} \tag{I.19}$$

$$x_I^*(\alpha_E, q, x_U, z_U) = \frac{d_I}{qY_H + (1-q)Y_L}.$$

This can always be supported as an equilibrium and is even unique if the uninformed investor has given a credit ($z_U = 1$) and if $x_I^* + x_U < 1$ holds. Anticipating this, the uninformed creditor accepts any offer that yields her at least zero profit in expectation, and the entrepreneur chooses the lowest value of x_U accepted by her:

$$z_U^*(\alpha_E, x_U) = \begin{cases} 1 & \text{if} \quad \int_0^1 \mu(q, r_U) \cdot z_I^* \cdot E[\phi_U(\alpha_I, r_U, x_I^*, Y) - d_U|q] \geq 0 \\ 0 & \text{else} \end{cases}$$

$$x_U^*(\alpha_I, q) \in \arg\max \frac{z_U^*(\alpha_E, x_U)}{x_U}.$$

Note that z_U^* is well-defined as neither r_I^* nor z_I^* are functions of z_U. The value for x_U^* can even be supported as an equilibrium if $Y_H - x_U^* - x_I^* \leq 0$ holds. Given that all types offer the same x_U, there is again a threshold above which all and below which none are carried out. It is given by

$$\frac{d_I}{q_L(\alpha_E, x_U)Y_H + (1 - q_L(\alpha_E, x_U))Y_L} + x_U = 1 \tag{I.20}$$

$$\Leftrightarrow q_L(\alpha_E, x_U) = \frac{d_I - (1 - x_U)Y_L}{(1 - x_U)(Y_H - Y_L)}. \tag{I.21}$$

Again, any level of x_U can be supported as an equilibrium. Given the threshold, U's payoff is given by

$$\frac{1 + q_L(\alpha_E, x_U^*)}{2} x_U^* Y_H + \frac{1 - q_L(\alpha_E, x_U^*)}{2} x_U^* Y_L \tag{I.22}$$

Note that U's profit is continuous and strictly increasing in the threshold and that the threshold is continuous and strictly decreasing in x_U (I.21). Hence, in equilibrium, U makes zero profit:

$$\frac{1 + q_L(\alpha_E, x_U^*)}{2} x_U^* Y_H + \frac{1 - q_L(\alpha_E, x_U^*)}{2} x_U^* Y_L = d_U \tag{I.23}$$

$$\Leftrightarrow x_U^* = \frac{2d_u}{[1 + q_L(\alpha_E, x_U^*)]Y_H + [1 - q_L(\alpha_E, x_U^*)]Y_L}. \tag{I.24}$$

Combining (I.20) and (I.24) yields the unique equilibrium threshold:

$$q_L^*(\alpha_E) = \frac{\frac{1}{2}(D + d_U - Y_H) + \sqrt{\frac{1}{4}(D + d_U - Y_H)^2 + Y_H d_I} - Y_L}{Y_H - Y_L}, \quad \text{(I.25)}$$

as shown in appendix 1.5. We can conclude that

Proposition I.9: *Under equity financing, there is the following sequential equilibrium:*

$$\textbf{\textit{E:}}\ x_U^* = \frac{2d_u}{[1 + q_L^*(\alpha_E)]Y_H + [1 - q_L^*(\alpha_E)]Y_L}$$

$$\textbf{\textit{U:}}\ z_U^* = \begin{cases} 1 & \textit{if} \quad E[\phi_U(\alpha_E, x_U, \frac{d_I}{qY_H + (1-q)Y_L}, Y) - d_U | q \geq q_L(\alpha_E, x_U)] \geq 0 \\ 0 & \textit{else} \end{cases}$$

$$\textbf{\textit{E:}}\ x_I^* = \frac{d_I}{qY_H + (1-q)Y_L}$$

$$\textbf{\textit{I:}}\ z_I^* = \begin{cases} 1 & \textit{if} \quad q \min[x_I, 1 - x_U]Y_H + (1-q)\min[x_I, 1 - x_U]Y_L \geq d_I \\ 0 & \textit{else.} \end{cases}$$

The uninformed investor's beliefs are $\mu(q, r_U) = 1, \forall q \in [0, 1], \forall r_U \geq d_U$.

We can make the following statement about the welfare properties of equity financing, which is established in appendix 1.6:

Proposition I.10: *Equity contracts perform better than informed creditor's priority, but worse than the pro-rata rule.*

Equity financing performs better than informed creditor's priority because the informed creditor is more likely to suffer from financing of inefficient projects. Compared to the pro-rata rule, equity is worse because for the pivotal type q_L, the informed creditor/investor receives relatively much compared to a debt contract where her share is determined by $d_I Y_L$ in bankruptcy for all types. Compared to informed creditor's priority, she receives relatively little. Hence, the results are better than under informed creditor's priority.

5. Conclusion

This chapter provides an additional justification for rules that subordinate owners' loans in bankruptcy: In an asymmetric information framework, where one creditor is fully informed about the project but the other is not, it is best to serve the uninformed party first in bankruptcy. In this case, information on the market is best used. The more the uninformed creditor receives in bankruptcy, the less severe the informational asymmetry. Then the informed creditor finances socially inefficient projects to a lesser extent or even not at all.

Thus, adverse selection can serve as an additional justification for the equitable subordination doctrine. This replenishes previous literature in this field, which justified this rule with moral hazard behavior after the contract has been made. In contrast to this chapter, the moral hazard approach only finds ambiguous results about the desirability of those rules.

In the introduction we discussed the question why the apparently desirable requalification should be mandatory law. Obviously, the legislator fears that such agreements will not work in practice. So far, however, there is not much theoretical background to this issue. The question how the stakeholders of a firm could distribute its cash flows in a more sophisticated way than just relying on equity and debt is not only important to the rules of equitable subordination.

Another difficult issue is of course, which criteria should be used as a proxy for superior information. German law stipulates a mandatory subordination of claims of owners of at least 10 % of the shares. Other possible criteria could include being part of the same corporate group or a long-lasting commercial relationship. However, as in reality the information environments tend to be more complex, this is an interesting question for future research.

II. Economic Analysis of Taking Rules: the Bilateral Case

The analysis focuses on a situation where a landowner and the government invest prior to the government's taking decision. When the government suffers from budgetary "fiscal illusion", optimal compensation amounts to the hypothetical value of the landowner's property had she invested efficiently. In contrast, under a government that maximizes social welfare, the only regime to induce the first best grants as compensation the social benefit of the taking. Consequently, if the government can only raise capital up to a certain amount, society may be better off under a non-benevolent government.

1. Introduction

The Fifth Amendment to the United States Constitution states "[...]nor shall private property be taken for public use, without just compensation". This and corresponding clauses in other legal systems, referred to as eminent domain, expropriations, or takings, have not only generated an enormous amount of legal cases, but have also been examined by economists.[1] Besides the basic question about the justification for eminent domain[2], economists and legal scholars are interested in how optimal compensation should look like. Whereas legal scholars often point out justice arguments[3], the economic literature focuses on the investment incentives of the victim of a taking, often a landowner. In a provocative article, Blume, Rubinfeld, and Shapiro (1984), who assume that the government acts to maximize social welfare, show that zero compensation often leads to efficient investment incentives for the landowner. Fair market value compensation induces, however, ex ante overinvestment in private property. The intuition is that the potential victim is fully insured and does not take those states of the world into account where a taking is socially desirable. Scholars have, since then, challenged the result that no compensation outperforms fair market value compensation. A straightforward argument is that risk averse

[1] Economists emphasize that "a taking" not only captures physical acquisitions. So called regulatory takings, e.g., modifying approach paths of an airport, must also be considered as a taking insofar as they may lower the value of property Hermalin (1995), pp. 64 f., Kaplow (1986), for an overview of cases, cf. Miceli and Segerson (1994).

[2] The common justification for this form of compulsory exchange can be found in the hold-out problem (see Cohen (1991); Goldberg, Merrill, and Unumb (1986); Miceli and Segerson (2007a)). Consider, as an example, that several parcels of land are required for a public project. In absence of eminent domain, owners have an incentive to delay their sale in order to extract parts of the project's social surplus. Munch (1976) challenges the desirability of eminent domain, claiming that it may cause increased transaction costs. Shavell (2010) finds, however, that eminent domain is socially desirable if the quantity of parcels is sufficiently large and the government does not know their private value.

[3] Many scholars argue that, even if a government exercises its power of eminent domain to maximize social welfare, it is necessary to compensate for the loss suffered by the taking (see e.g., Michelman (1967)).

individuals are not able to insure themselves against takings due to market failure. Consequently, the government has to provide insurance in the form of compensation (see e.g., Blume and Rubinfeld (1984), pp. 582 ff. and Calandrillo (2005)). Other articles point out "demoralization costs" that accrue to potential losers "from the realization that no compensation is offered" (Fischel and Shapiro (1988); Michelman (1967), p. 1214).

An important branch of the literature assumes that the government suffers from "fiscal illusion", i.e., the perceived cost of a taking is identical to compensation.[4] In such frameworks, an important motive behind compensation is to influence the government's behavior. As a noteworthy example, Hermalin (1995) demonstrates, in a setting where only the landowner invests, that compensation should amount to the social benefit of the taking. Alternatively, related to the famous COASE (1960) theorem, the first best can also be achieved if the landowner has to compensate the government in absence of a taking. In both situations, the landowner maximizes expected social welfare and therefore has efficient incentives to invest. Tideman and Plassmann (2005) argue that the announcement of a taking is already a partial taking unless the owner is fully compensated. In their framework, the government has to compensate for this partial taking to ensure fairness and to induce the government to make the efficient announcement. A large branch of the literature considers the so called constitutional choice approach to eminent domain (cf. Fischel and Shapiro (1989); Innes (1997); Miceli (2008); Nosal (2001)). Individual landowners, acting from behind a veil of ignorance, choose compensation law without knowing which parcels of land will be taken. Compensation is financed by a tax levied onto the property value. The main insight gained from this approach is that overinvestment incentives generated by compensation regimes are often

[4] This may be the case if the government's behavior is driven by lobbyism. Bell (2009) argues that the economic analysis of eminent domain also applies to situations where the state is not even involved.

canceled out because tax makes investment in property less attractive.

This chapter goes one step further than Hermalin (1995). If the government suffers from fiscal illusion and therefore has non-benevolent motives, it makes sense to consider a situation where not only the landowner, but also the government may invest ex ante. Whereas the landowner invests to increase the value of her property, the government invests to increase the expected social benefit of the taking. As an example, the landowner may invest in a new fodder silo or storehouse whereas the government may invest to gather information on how to use the landowner's property as a disposal site for nuclear waste. Other examples include a government that invests to connect the landowner's property to the existing road and rail network or a government that uses its power of eminent domain on behalf of an airport. If the government is non-benevolent, compensation regimes thus influence both investment decisions and also the ex post taking decision of the government. Suffering from fiscal illusion, it initiates a taking whenever the amount of compensation it has to pay is less or equal than the social benefit of the taking.

We find, as our main result, that compensation should be based on the hypothetical value of the landowner's property had she invested efficiently. Under this regime, the common problem that the landowner overinvests to reduce the probability of a taking or to increase compensation does not occur. Consequently, the landowner has an incentive to choose the socially best response to the investment of the government. The government, in turn, internalizes the benefit of its investment in exactly the same states as in the social optimum and thus is a residual claimant of the bilateral relationship. In equilibrium, both parties have efficient incentives to invest. This result can be related to the economic analysis of contract law where it is well-known that the legal breach remedy of expectation damages, if based on socially optimal investment, induces an efficient breach decision and efficient investment incentives (Cooter (1985), p. 18; Schweizer (2005), pp. 250 ff.). In contrast, the most commonly proposed compensation regimes perform poorly. If no compensation is paid, the government initiates too many takings and, hence, the landowner underinvests in her property. This result stands in contrast to Blume, Rubinfeld, and Shapiro (1984) where, if the taking decision depends on the landowner's investment, the no compensation regime induces overinvestment. The compensation regime proposed by Hermalin (1995) that grants as compensation the social benefit of the taking, henceforth social benefit compensation regime, induces the government to not invest at all because it does not internalize any benefit of its investment.

As a benchmark, we consider the situation that the government acts benevolently, i.e., maximizes expected social welfare. We establish, under plausible assumptions, that the social benefit compensation regime is the only regime to generally induce the first best. This result leads to an interesting implication. If the government can only raise capital up to an amount below the social benefit, no optimal compensation regime may be available. Consequently, society may be better off if the government suffers from fiscal illusion.

An important contribution of this chapter is to present a generally applicable machinery that does not require differentiability and does not impose assumptions on the shape of distribution functions. This machinery allows us to derive our results in a simple but elegant way.[5]

The chapter is organized as follows. In section 2, we introduce our model of bilateral investment. We then analyze under the assumption that the government is non-benevolent the efficiency of different compensation regimes in section 3. In section 4, we consider, as a benchmark, the situation that the government is benevolent. Section 5 concludes.

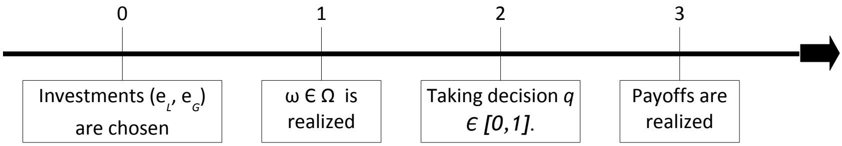

Figure II.1.: Timeline of the model

2. The model

We consider a model with two risk-neutral parties. A landowner, also referred to as "she", faces the risk that in the future the government or "it" may take her property in order to provide a public good[6] (see Figure II.1). At date 0, before it is known whether a taking occurs, the landowner may invest to increase the expected private value of her property. Likewise, the government invests to increase the expected social value of the public good. We denote the cost of their investments by $e_L \in [0, e_L^{max}]$ and $e_G \in [0, e_G^{max}]$, respectively, and assume that investment is asset-specific. If the government does not take the landowner's property, its investment is lost whereas the landowner's investment is beneficial only in absence of a taking. As an example, consider a farmer who may invest in a new fodder silo or a storehouse. The government may consider using the farmer's land to construct a repository for nuclear waste. Here, the government invests to obtain information about the nature of the ground and to tailor the repository to the geologic conditions of the area. At date 1, the state of the world $\omega \in \Omega$ is realized. Hence, the landowner's private valuation of her property $(1-q)V(e_L, \omega)$, the social value of the public good $qS(e_G, \omega)$ and the amount of compensation to be paid $qC(e_L, e_G, \omega)$, values that depend on the government's taking decision

[5]The machinery of the present chapter is closely related to the one used in Göller (2011), a paper that analyzes the efficiency of expectation damages in a situation of bilateral cooperative investment.

[6]The two defining properties of a public good, non-rivalry and non-excludability, are not crucial for our analysis. Therefore, the term "public good" must not be understood in a narrow sense, but describes any good provided by public authorities.

$q \in \{0, 1\}$, become commonly known. In this decision, to be made at date 2, $q = 0$ means that the landowner keeps her property whereas $q = 1$ implies that it is taken and the public good is supplied. Thus, the property can either be used by the landowner or the government, but not by both at the same time. We assume that the government cannot ex ante commit on an ex post taking decision and that the landowner does not draw utility from the provision of the public good.[7] In the next section, we consider the case that the government initiates a taking if the amount of compensation it has to pay does not exceed the potential social value of the public good. In contrast, we assume in section 4 that the government takes the property whenever it is socially desirable to do so. Finally, at date 3, the payoffs are realized. We discuss them in detail in section 3 and 4, for both the non-benevolent and the benevolent government, respectively. Throughout this chapter, we assume that all information but investment is common knowledge and use the following notation and assumptions:

> **Assumption 1** For any $e_L \in [0, e_L^{max}]$, $e_G \in [0, e_G^{max}]$ and $\omega \in \Omega$, $V(e_L, \omega) > 0$ and $S(e_G, \omega) > 0$.

> **Assumption 2** For any $\omega \in \Omega$, $V(e_L, \omega)$ is monotonically increasing in e_L and $S(e_G, \omega)$ is monotonically increasing in e_G.

It directly follows from Assumption 2 that the probability that the value of the public good exceeds the landowner's private valuation of her property is increasing in e_G and decreasing in e_L. Let us denote the ex post social surplus minus investment by

$$W(e_L, e_G, \omega, q) = qS(e_G, \omega) + (1 - q)V(e_L, \omega) - e_L - e_G.$$

[7]The potential value of the public good to society, $S(e_G, \omega)$, can also be understood as the social benefit of the taking. This expression should not be confused with the social net benefit, $qS(e_G, \omega) - (1 - q)V(e_L, \omega)$.

For given investments e_L, e_G and state of the world ω, it is maximized by the socially efficient taking decision

$$q^*(e_L, e_G, \omega) \in \arg\max_{q \in \{0,1\}} W(e_L, e_G, \omega, q).$$

This implies that a benevolent social planner would take the landowner's property, $q = 1$, whenever the social benefit of the taking is at least as high as the landowner's valuation of her property, $S(e_G, \omega) \geq V(e_L, \omega)$. We assume that the efficient investment levels, denoted (e_L^*,e_G^*), uniquely maximize the expected social surplus

$$E[W(e_L, e_G, \omega, q^*(e_L, e_G, \omega))]$$

in $[0, e_L^{max}] \times [0, e_G^{max}]$ contingent on an efficient taking decision. Let us consider two more benchmarks that will prove useful for our analysis. First, we are interested in the landowner's optimal investment in absence of the risk of a taking. This private optimal level, denoted e_L^p, uniquely maximizes

$$E[V(e_L, \omega)] - e_L \tag{II.1}$$

in $[0, e_L^{max}]$. Second, let us consider the case that a taking is always desirable from a social perspective. Then, the government's socially optimal investment level, denoted e_G^p, uniquely maximizes

$$E[S(e_G, \omega)] - e_G$$

in $[0, e_G^{max}]$. It is straightforward to show that $e_L^p \geq e_L^*$ and $e_G^p \geq e_G^*$ (see Appendix 2.1).

3. Non-benevolent government

As correctly observed by Hermalin (1995), one important motive behind the demand for just compensation is to restrain the government from the tyrannical use of its right of eminent domain. The underlying idea is that a government often acts on behalf of the interest of the majority essentially ignoring the interest of a single property owner.[8] In this section, we analyze how commonly proposed compensation regimes perform with respect to efficiency. A regime is socially optimal if the efficient ex post taking decision by the government and, contingent on that, efficient bilateral investment can be established as an equilibrium. We find that the first best is attainable by a regime that grants as compensation the potential value of the landowner's property had she invested e_L^* ex ante.

The non-benevolent government internalizes the benefit of the public good but may have to bear compensation costs.[9] Its ex post payoff minus investment is given by

$$U_G(e_L, e_G, \omega, q) = q[S(e_G, \omega) - C(e_L, e_G, \omega)] - e_G.$$

For given investments (e_L,e_G) and state of the world ω, the government's taking decision solves

$$Q^G(e_L, e_G, \omega) \in \underset{q \in \{0,1\}}{\arg\max}\, U_G(e_L, e_G, \omega, q).$$

Hence, the government initiates a taking whenever the value of the public good exceeds the amount of compensation it has to pay. If a taking occurs, the landowner receives compensation. If not, she enjoys the benefit of her property. Her ex post payoff minus investment thus amounts to

$$U_L(e_L, e_G, \omega, q) = (1 - q)V(e_L, \omega) + qC(e_L, e_G, \omega) - e_L.$$

We can now define the government's private best response to investment of the landowner as

$$e_G^{BR}(e_L) := \underset{e_G \in [0, e_G^{max}]}{\arg\max}\; E[U_G(e_L, e_G, \omega, Q^G(e_L, e_G, \omega))]$$

[8] As an alternative motivation, consider that the power of eminent domain is often used not in order to provide a public good but in the interest of a private enterprise. In the legal literature, there is a debate about whether such takings fulfill the public use requirement, cf. Kelly (2006) and Pritchett (2003).

[9] Recall that the government neglects the landowner's interest and therefore does not take the landowner's benefit of compensation into account.

and the landowner's private best response to investment of the government as

$$e_L^{BR}(e_G) := \underset{e_L \in [0, e_L^{max}]}{\arg\max} E[U_L(e_L, e_G, \omega, Q^G(e_L, e_G, \omega))].$$

Moreover, we define the socially best response to investment of the landowner as

$$e_G^{SBR}(e_L) := \underset{e_G \in [0, e_G^{max}]}{\arg\max} E[W(e_L, e_G, \omega, Q^G(e_L, e_G, \omega))]$$

and the socially best response to investment of the government as

$$e_L^{SBR}(e_G) := \underset{e_L \in [0, e_L^{max}]}{\arg\max} E[W(e_L, e_G, \omega, Q^G(e_L, e_G, \omega))].$$

In United States Case Law, just compensation is usually interpreted as fair market value (Miceli and Segerson (2007b), p. 277). Let us interpret fair market value as the value of the landowner's property in absence of a taking, $C(e_L, e_G, \omega) = V(e_L, \omega)$. Under a regime that grants fair market value, henceforth full compensation regime (see Blume, Rubinfeld, and Shapiro (1984)), the landowner's ex post payoff minus investment amounts to

$$U_L^{FC}(e_L, e_G, \omega, q) = V(e_L, \omega) - e_L.$$

The government's payoff amounts to ex post social surplus minus the landowner's payoff. It is given by

$$U_G^{FC}(e_L, e_G, \omega, q) = W(e_L, e_G, \omega, q) - [V(e_L, \omega) - e_L] =$$
$$q[S(e_G, \omega) - V(e_L, \omega)] - e_G.$$

We can derive the following proposition:

Proposition II.1: *Under the full compensation regime, in any subgame-perfect equilibrium: (i) The government's taking decision is efficient,* $Q^G(e_L, e_G, \omega) = q^*(e_L, e_G, \omega)$. *(ii) The landowner invests as if there was no risk of taking and irrespectively of the government's investment,* $e_L^{BR}(e_G) = e_L^p \geq e_L^*$ *for all* $e_G \in [0, e_G^{max}]$. *(iii) The government chooses a socially best response to the landowner's investment,* $e_G \in e_G^{SBR}(e_L^p)$.

Proof. (i) The government's taking decision is efficient, $Q^G(e_L, e_G, \omega) = q^*(e_L, e_G, \omega)$, because it initiates a taking whenever $S(e_G, \omega) \geq V(e_L, \omega)$. (ii) The second statement is true because the landowner's expected payoff

$$E[V(e_L, \omega)] - e_L$$

is equivalent to the one in absence of the risk of a taking (see equation (II.1)). (iii) Taking into account the landowner's investment and its own ex post taking decision, $Q^G(e_L, e_G, \omega) = q^*(e_L, e_G, \omega)$, the government's expected payoff is given by

$$E[W(e_L^p, e_G, \omega, q^*(e_L^p, e_G, \omega))] - E[V(e_L^p, \omega)] + e_L.$$

Since $E[V(e_L^p, \omega)] - e_L$ does not depend on the government's investment, it chooses a socially best response to the landowner's investment. ■

For the landowner, we get the same overinvestment result as in Blume, Rubinfeld, and Shapiro (1984). She overinvests because she is fully insured and hence does not take those states of the world into account where a taking is socially desirable. The government, however, chooses the efficient ex post taking decision and even the socially best response to the landowner's investment. This is the case because the government is in the position of a residual claimant of the bilateral relationship. It receives total social surplus minus the value of the landowner's property, a term that is constant with respect to the government's investment. Thus, even though the landowner overinvests, the full compensation regime may not be as undesirable as in Blume, Rubinfeld, and Shapiro (1984).

Perhaps the best known result of Blume, Rubinfeld, and Shapiro (1984) is that if no compensation is paid, the first best can be attained if the landowner's investment does not influence the probability of a taking.

Under the no compensation regime, the landowner's ex post payoff minus investment amounts to

$$U_L^{NC}(e_L, e_G, \omega, q) = (1 - q)V(e_L, \omega) - e_L.$$

Since the government has to pay no compensation and neglects the landowner's interest, its payoff is given by

$$\begin{aligned} U_G^{NC}(e_L, e_G, \omega, q) &= qS(e_G, \omega) - e_G \\ &= W(e_L, e_G, \omega, q) - (1-q)V(e_L, \omega) + e_L. \end{aligned}$$

We can establish the following proposition:

Proposition II.2: *Under the no compensation regime, in any subgame-perfect equilibrium: (i) The government always takes the landowner's property,* $Q^G(e_L, e_G, \omega) = 1$. *(ii) Consequently, the landowner does not invest at all,* $e_L^{BR}(e_G) = 0$ *for all* $e_G \in [0, e_G^{max}]$. *(iii) The government chooses a socially best response to the landowner's investment,* $e_G \in e_G^{SBR}(0)$.

Proof. (i) The first claim is true because $S(e_G, \omega)$ is strictly greater than zero. (ii) Because the landowner's expected payoff is equivalent to

$$E[U_L^{NC}(e_L, e_G, \omega, 1)] = -e_L,$$

she does not invest at all. (iii) Taking into account the landowner's investment and its own ex post taking decision, $Q^G(e_L, e_G, \omega) = 1$, the government's expected payoff is given by

$$E[W(0, e_G, \omega, 1)] - E[0V(0, \omega)] + e_L = E[W(0, e_G, \omega, 1)] + e_L.$$

Thus, given that a taking occurs with certainty, the government plays a socially best response. ■

In contrast to Blume, Rubinfeld, and Shapiro (1984), the no compensation regime performs poorly in our setting. The government always takes the landowner's property and therefore induces her to not invest at all. The government's investment corresponds to our third benchmark where a taking is always socially desirable, $e_G^{BR}(e_L) = e_G^p$. Note that e_G^p is generally not a socially best response to efficient investment of the landowner (see Appendix 2.1). It is, however, an optimal choice if takings occur with certainty.

Hermalin (1995) shows, in a setting where the state is non-benevolent but only the landowner invests, that the first best can be induced by a regime that grants the landowner as compensation the social benefit of the taking, $C(e_L, e_G, \omega) = S(e_G, \omega)$. Under this regime, henceforth social benefit compensation regime, the landowner's ex post payoff minus investment amounts to

$$\begin{aligned} U_L^{SBC}(e_L, e_G, \omega, q) = (1-q)V(e_L, \omega) + & qS(e_G, \omega) - e_L \\ = & W(e_L, e_G, \omega, q) + e_G. \end{aligned}$$

And hence the government's payoff is given by

$$U_G^{SBC}(e_L, e_G, \omega, q) = -e_G.$$

In principle, the government is indifferent between initiating a taking or not. We can then establish the following proposition:

Proposition II.3: *Under the social benefit compensation regime, assuming that the government initiates a taking whenever it is socially desirable, we can establish the following subgame-perfect equilibrium outcome. (i) The government does not invest at all, $e_G^{BR}(e_L) = 0$ for all $e_L \in [0, e_L^{max}]$. (ii) The landowner's best response is equivalent to the socially best response, $e_L^{BR}(0) = e_L^{SBR}(0)$.*

Proof. (i) Obvious. (ii) The landowner's expected payoff amounts to

$$E[W(e_L, 0, \omega, q^*(0, e_L, \omega))] + e_G.$$

Hence, she chooses the socially optimal best response. ■

In contrast to Hermalin (1995), the social benefit compensation regime performs poorly in our setting. The government does not internalize any benefit of its investment and thus has no incentive to invest. Suppose that the landowner receives as compensation some fraction $\alpha \in (0, 1)$ from the social benefit of the taking. Because $(1-\alpha)S(e_G, \omega) > 0$, the non-benevolent government always initiates a taking. Since the landowner's investment does not influence the value of the public good, she has no incentive to invest.

We have established that all standard compensation regimes fail to induce the first best. Consider a regime, henceforth referred to as social optimal property value compensation regime, where the landowner receives as compensation the hypothetical value of her property had she invested efficiently, $C(e_L, e_G, \omega) = V(e_L^*, \omega)$. Under this regime, the landowner receives:

$$\begin{aligned} U_L^{SOPVC}(e_L, e_G, \omega, q) &= (1-q)V(e_L, \omega) + qV(e_L^*, \omega) - e_L \\ &= W(e_L, e_G, \omega, q) - qS(e_G, \omega) + qV(e_L^*, \omega) + e_G. \end{aligned}$$

Consequently, the government's payoff is given by

$$\begin{aligned} U_G^{SOPVC}(e_L, e_G, \omega, q) &= q[S(e_G, \omega) - V(e_L^*, \omega)] - e_G \\ &= qS(e_G, \omega) - V(e_L^*, \omega) + (1-q)V(e_L^*, \omega) - e_G \\ &= W(e_L^*, e_G, \omega, q) - V(e_L^*, \omega) + e_L^*. \end{aligned}$$

This allows us to establish the main proposition of this chapter:

Proposition II.4: *Under the social optimal property value compensation regime, the socially efficient investment levels (e_L^*, e_G^*) and the socially efficient ex post taking decision $Q^G(e_L^*, e_G^*, \omega) = q^*(e_L^*, e_G^*, \omega)$ constitute the unique subgame-perfect equilibrium outcome.*

Proof. The government initiates a taking whenever $S(e_G, \omega) \geq V(e_L^*, \omega)$. We can therefore write the government's ex post taking decision as $Q^G(e_L, e_G, \omega) = q^*(e_L^*, e_G, \omega)$.

Let us establish that $e_G = e_G^*$ is the unique best response to any investment of the landowner. The government's expected payoff is given by

$$E[W(e_L^*, e_G, \omega, q^*(e_L^*, e_G, \omega))] - E[V(e_L^*, \omega)] + e_L^*$$

Because (e_L^*, e_G^*) uniquely maximize expected welfare and $-E[V(e_L^*, \omega)] + e_L^*$ does not depend on the government's investment, e_G^* uniquely maximizes the government's expected payoff.

Given the government's taking decision and investment, the landowner's expected payoff amounts to

$$E[W(e_L, e_G^*, \omega, q^*(e_L^*, e_G^*, \omega))] - E[q^*(e_L^*, e_G^*, \omega)(S(e_G^*, \omega) - V(e_L^*, \omega))] + e_G^*.$$

To check that $e_L = e_L^*$ is the unique best response, we show that it maximizes
$E[W(e_L, e_G^*, \omega, q^*(e_L^*, e_G^*, \omega))]$. Take any $e_L \neq e_L^*$, then it must hold that

$$\begin{aligned} &E[W(e_L^*, e_G^*, \omega, q^*(e_L^*, e_G^*, \omega))] \\ >&E[W(e_L, e_G^*, \omega, q^*(e_L, e_G^*, \omega))] \\ \geq&E[W(e_L, e_G^*, \omega, q^*(e_L^*, e_G^*, \omega))]. \end{aligned} \tag{II.2}$$

The first inequality follows from e_L^* and e_G^* being unique welfare maximizers. The second and the third line of (II.2) only differ in the ex post taking decision. Because the taking decision is socially optimal and conditions on true investment in the second line but on e_L^* in the third line, the second inequality must hold. We have established that e_L^* is the unique best response to e_G^*, which proves the claim. ■

The intuition behind our main result is the following. The government takes the property whenever the compensation it has to pay is less than or equal to the social benefit of the taking. Since compensation is equivalent to the hypothetical value of the landowner's property had she invested e_L^*, the taking decision depends on the government's but not on the landowner's investment. If the government invests $e_G = e_G^*$, it initiates a taking in exactly the same states of the world a benevolent social planner would do so. Consequently, the landowner internalizes the benefit of her investment with exactly the same probability as in the first best. Therefore $e_L = e_L^*$ is the unique best response to efficient investment of the government. If the landowner invests efficiently, the government receives expected social surplus minus the landowner's benefit, a term that is constant with respect to the government's investment. Because e_G^* is the socially best response to e_L^*, it must also be the best response for the government.

Theorem II.1: *The investment levels induced by the compensation regimes discussed in this section can be ranked in the following way:*[10]

$$\forall e_L \in e_L^{SBC} : e_L^{FC} = e_L^p \geq e_L \geq e_L^{SOPVC} = e_L^* \geq e_L^{NC} = 0 \qquad \text{(II.3)}$$
$$\forall e_G \in e_G^{FC} : e_G^{NC} = e_G^p \geq e_G^{SOPVC} = e_G^* \geq e_G \geq e_G^{SBC} = 0. \qquad \text{(II.4)}$$

All regimes other than the SOPVC regime, however, cannot be ranked with respect to their welfare properties.

Proof. See Appendix 2.2. ■

Any regime other than the SOPVC regime fails to induce the first best in different respects. Under different parameter constellations, the size of these inefficiencies may vary greatly. Hence, any of these regimes may theoretically outperform the other two. In situations where the ex ante probability of a taking is low, the full compensation regime performs reasonably well. The government, even though it is non-benevolent, chooses a social optimal best response to the landowner's investment. The landowner's overinvestment, which occurs because the landowner is fully insured and does not take those states of the world into account where a taking is socially desirable, may be considered negligible. Proposition 4 suggests that if one believes that the ex ante probability of a taking is substantial, compensation should not be based on actual but on socially optimal investment. The complexity of computing first-best compensation is, however, higher under the social optimal property value compensation regime. Blume, Rubinfeld, and Shapiro (1984), who assume that the government is benevolent, derive a related result. If the government can commit to initiate a taking whenever the social benefit of the taking is higher than the hypothetical value of the landowner's

[10] Here, the notation is as follows. The landowner's optimal investment level under the full compensation regime is denoted by e_L^{FC}. Because the landowner's optimal investment need not be unique under the social benefit compensation regime, e_L^{SBC} denotes the set of optimal investment levels under this regime. The remaining variables are defined in a similar way, where SOPVC stands for social optimal property value compensation and NC for no compensation.

property had she invested efficiently, any lump sum compensation plan induces the landowner to invest according to the first best. Thus, the benevolent government would like to commit itself to exactly the same ex post taking decision the non-benevolent government chooses out of its own interest. Next section, we consider the situation that the government is benevolent but cannot commit to any ex post taking decision.

4. Benevolent government

In this section, the government's interest coincides with those of a benevolent social planner. We consider a wide class of compensation regimes and derive that, under certain plausible assumptions, the social benefit compensation regime is the only one to generally induce the first best. The government's ex post payoff minus investment is equivalent to ex post social welfare minus investment. It is given by

$$U_G(e_L, e_G, \omega, q) = qS(e_G, \omega) + (1-q)V(e_L, \omega) - e_L - e_G.$$

The government uses its right of eminent domain whenever it is socially desirable to do so, $Q^G(e_L, e_G, \omega) = q^*(e_L, e_G, \omega)$. At the investment stage, it chooses the socially best response to the investment strategy of the landowner contingent on its own ex post taking decision. Consequently, the first best can be established as an equilibrium whenever the landowner's investment constitutes a socially best response to the government's investment. The landowner's ex post payoff minus investment is the same as in the previous section. It amounts to

$$U_L(e_L, e_G, \omega, q) = (1-q)V(e_L, \omega) + qC(e_L, e_G, \omega) - e_L.$$

In the following, we only consider compensation regimes that are non-punishing. In any state of the world $\omega \in \Omega$, the amount of compensation paid to the landowner $C(e_L, e_G, \omega)$, is non-decreasing in e_L. The rationale behind this restriction is that the idea behind compensation is to protect but not to punish the landowner. Moreover, let us assume that compensation may not exceed the social benefit of the taking, $C(e_L, e_G, \omega) \leq S(e_G, \omega)$ for all $\omega \in \Omega$. The government may be wealth-constrained or public pressure may prevent an exceedingly high amount of compensation. We establish the following proposition:

Proposition II.5: *If compensation is non-punishing and may not exceed the social benefit of the taking, only the social benefit compensation regime, $C(e_L, e_G, \omega) = S(e_G, \omega)$, generally induces the first best. Any other regime induces that the landowner's best response to efficient investment of the government is to overinvest, $\forall e_L \in e_L^{BR}(e_G^*), e_L \geq e_L^*$.*

Proof. For ease of notation, let us omit the arguments e_G^* and ω. The landowner's expected payoff is given by

$$\begin{aligned} E[U_L(e_L)] =& E[(1 - Q^*(e_L))V(e_L)] + E[Q^*(e_L)C(e_L)] - e_L \\ =& E[W(e_L, Q^*(e_L))] - \{E[Q^*(e_L)(S - C(e_L))] + e_G^*\}. \end{aligned} \quad \text{(II.5)}$$

Under the social benefit compensation regime, (II.5) coincides with expected social welfare. Thus, the landowner has efficient incentives to invest. Let us consider any other compensation regime and assume that there exists some $e_L < e_L^*$ such that $E[U_L(e_L)] \geq E[U_L(e_L^*)]$. Because expected social surplus is uniquely maximized by e_L^* and e_G^*, this can only be the case if

$$-E[Q^*(e_L)(S - C(e_L))] > -E[Q^*(e_L^*)(S - C(e_L^*))].$$

Let us subtract $E[Q^*(e_L^*)C(e_L)]$ from both sides of the inequality. This term represents the hypothetical expected value of compensation if the landowner invests e_L, but the government bases its taking decision on e_L^*. After reorganizing, we get

$$-E[(q^*(e_L) - q^*(e_L^*))(S - C(e_L))]] > E[Q^*(e_L^*)C(e_L^*)] - E[Q^*(e_L^*)C(e_L)]. \quad \text{(II.6)}$$

The right-hand side of (II.6) is greater or equal than zero because the expected amount of compensation is non-decreasing in e_L. In equation (II.6), we consider the expected value of the social benefit of the taking minus compensation in all states of the world where a taking occurs if the decision is based on e_L, but not if it is based on e_L^*. The left-hand side of (II.6) is negative because in any state it must hold that compensation does not exceed the social benefit of the taking. If compensation is equivalent to the social benefit of the taking in all states, the regime must coincide with the social benefit compensation regime. Thus, under any other regime, (II.6) is violated and therefore $\forall e_L \in e_L^{BR}(e_G^*), e_L \geq e_L^*$.[11]

■

The intuition behind Proposition II.5 is straightforward. The landowner has an incentive to overinvest for two reasons. First, in contrast to the objective of a benevolent social planner, the landowner's investment may increase her expected amount of compensation whereas it does not affect the value of the public good. Second, if a taking occurs, the landowner receives an amount of compensation that is generally less than the social benefit of the taking. She thus has an incentive to overinvest to reduce the probability that the government takes her property. Under the social benefit compensation regime both sources of inefficiency do not exist. Consequently, the landowner has efficient incentives to invest.

All regimes examined in the previous section are included in the class of compensation regimes considered in Proposition II.5. It is worth mentioning that Proposition II.5 contradicts the viewpoint expressed in Miceli and Segerson (2007b) that, under a benevolent government, a regime that grants the full value of the landowner's land at its efficient level of investment induces the first best.[12] Recall that this regime, called social optimal property value compensation regime in the previous sec-

[11]For any regime other than the social benefit compensation regime it is always possible to construct an example where $e_L^{BR}(e_G^*) > e_L^*$. In such an example, it must hold that $E[(q^*(e_L) - q^*(e_L^*))C(e_L)] << E[(q^*(e_L) - q^*(e_L^*))S]$.

[12]See Appendix 2.3 for a numerical example.

tion, does induce the first best if the government is non-benevolent. The classical Blume, Rubinfeld, and Shapiro (1984) no compensation result is also connected to Proposition II.5: If the probability of a taking is independent of investment, any lump sum compensation plan induces the first best. In that case, in equation (II.5) the term in the braces does not depend on the landowner's investment. Hence, her investment incentives coincide with those of a benevolent social planner.

5. Conclusion

This chapter considers a situation where both the government and the landowner invest before the government may use its power of eminent domain. This literature has begun blooming with the seminal work by Blume, Rubinfeld, and Shapiro (1984).

The analysis suggests that if the ex ante probability of a taking is low, a regime that grants due compensation performs reasonably well. The government has efficient ex ante and ex post incentives, even if it is non-benevolent and thus disregards the interests of the landowner. The landowner's overinvestment may be considered trivial relative to the social optimum in such a situation. There also exist, however, situations where the ex ante probability of a taking is substantial. As an example, consider a situation where a supermarket owner knows that her property will be taken because the government plans to construct a bypass road where the supermarket is located. The owner, knowing that she is fully insured, has a substantial incentive to invest money in her market.

Perhaps the most interesting finding is that social welfare may be higher under the non-benevolent government. If the government is benevolent, only the social benefit compensation regime is generally able to induce the first best. If, however, the government is wealth-constrained, i.e., can only raise capital up to a certain amount that lies below the social benefit of the taking, the social benefit compensation regime is not available. Thus, there may not exist any compensation regime to induce the first best. If the government is non-benevolent, optimal compensation is equivalent to the hypothetical value of the landowner's property had she invested efficiently. This amount of compensation is, given that a taking occurs, generally less than the social benefit of the taking. Since, in practice, compensation is financed by taxes that are distorting, the social benefit compensation regime generates excess burdens to society. Consequently, society may be better off if the government is non-benevolent.

According to U.S. law, one of the main motives behind compensation is that compensation should be just. If the government is non-benevolent, the optimal compensation regime grants to the landowner, in equilibrium, exactly the value of her property. In other words, she is perfectly insured against the government's power of eminent domain. Under the social benefit compensation regime, which is the only regime to be generally optimal if the government is benevolent, the landowner receives the value of the public good. Obviously, this amount may exceed the private value of the landowner's property by far.

It is also important to emphasize that one should distinguish between two forms of public actions. First, law constitutes a set of rules that both the government and the landowner have to follow. Of course, one of the main goals of law should be to maximize social welfare. In contrast, the government's objectives may, as explained, not coincide with those of a benevolent social planner.

For future research, it seems to be an interesting prospect to consider a setting where the government is non-benevolent but subject to judicial control with respect to the necessity of the taking. Ex post, the government may only initiate a taking whenever it is socially desirable. Ex ante, however, the government invests to maximize the difference between the social benefit of the taking and the amount of compensation it has to pay.

III. Breakdown in Multilateral Negotiations

We analyze a complete information multilateral bargaining model in which a buyer is to purchase several complementary goods from several sellers. Binding cash-offer contracts are used to govern transactions. In contrast to the preexisting literature, we do not normalize the parties' reservation utilities to zero. This allows us to demonstrate that in a large class of bargaining games a complete breakdown of negotiations can occur as the unique equilibrium outcome even if only two sellers are present.

1. Introduction

Why do we observe union strikes? Why do negotiations about contiguous parcels of land owned by several parties often break down? Why has the government the right of eminent domain? Why is there a need for a mandatory bankruptcy procedure? These and similar questions boil down to the issue why rational parties often are not able to achieve the full gains of trade.

In the present chapter, we consider a bargaining situation where several sellers own exactly one piece of property. A central party needs to acquire all pieces of property to start a profitable project. Thus, from its perspective the pieces are complements. In the famous example of Coase (1960), a railroad company may only be able to extent its network if it manages to acquire the land of several landowners. Other examples include an entrepreneur who negotiates with several unions or an insolvency trustee that is in negotiations with different creditors. In the present chapter, we consider as our leading example an airport that wants to construct a new runway and needs to acquire land from several farmers. As often done in the previous literature on extensive form bargaining games, see e.g. Cai (2000) and Menezes and Pitchford (2004), we limit the contract space to "binding cash-offer contracts". Once an agreement has been reached, the airport pays the farmer and the farmer leaves the game. Thus, we do not consider contingent contracts where the airport only has to pay the agreed upon price if it reaches an agreement with all farmers. Binding cash-offer contracts are simple and easy to enforce and therefore often used in land procurement, see e.g. Cai (2000, p. 261).

In contrast to the previous literature, see e.g. Cai (2000), we do not normalize the farmers' reservation utilities to zero. This normalization is an innocent assumption if for any parcel the airport and the farmers have the same stand-alone valuation. However, the airport may not be able to run a farm and may not be able to sell it without a loss should it have failed to acquire the land from all farmers.[1] As we will see, it is this assumption that crucially drives our main result that a breakdown of negotiations may be the unique equilibrium outcome even if only two farmers are in the game. Compared to Cai (2000), this is a strong result. In his article, a breakdown can only occur if at least four farmers are present and even if it does it exists only as one of multiple equilibria. Intuitively, a breakdown may occur because when the airport negotiates with the last farmer all previous payments to the other farmers are sunk. Thus, these payments do not influence the outcome of the negotiations. Consequently, it may be the case that the sum of the last farmer's negotiation surplus and the previous payments is higher than the value of the airport's project. Anticipating this problem, the airport has an incentive not to reach an agreement with the previous farmers. In the present chapter, we also depart from the previous literature in the way we establish our breakdown result. We do not only consider a few selected bargaining games, but instead prove that breakdown equilibria exist in a large class of games. To do so, we identify a few sub-histories and argue that if an agreement is reached at least one of them must occur on the equilibrium path. Ruling out that any of them may occur then directly allows us to conclude that a breakdown of negotiations must be the unique equilibrium outcome. Moreover, we also explain that a breakdown equilibrium is more likely to exist if the farmers are patient compared to the airport and if the total bargaining cake, that consists of the profit of the runway minus the farmers' stand-alone valuations, is small. Finally, we extend our model to N farmers. We demonstrate in a particular bargaining game that if the number of farmers is sufficiently large, a breakdown constitutes the unique equilibrium outcome even if the total bargaining cake is very large.

Whereas the cooperative bargaining approach that goes back to Nash Jr

[1] Likewise, an agreement between an insolvency trustee and a *single* creditor or an entrepreneur and a *single* union may be inefficient because of negotiation costs or because of spillover effects from with other parties benefit.

(1950) can naturally not explain a complete breakdown of negotiations, there have been numerous other attempts to demonstrate bargaining inefficiencies in non-cooperative frameworks. Bargaining inefficiencies are straightforward in models of asymmetric information.[2] The rejection of an offer can be a signal to be of a particular type. Therefore, it may be optimal to reject an offer, hoping that the next offer is better. In settings of full information, however, attempts to explain bargaining inefficiencies have been less successful. This is surprising as this strand of the literature has begun blooming as early as with the seminal work by Rubinstein (1982). In the preexisting literature a costly delay or a total breakdown of negotiations may only exist as one of multiple equilibria. Examples include van Damme, Selten, and Winter (1990), Fernandez and Glazer (1991), Haller and Holden (1990), and Busch and Wen (1995). In their models, delay can occur because parties "agree to delay". Moreover, delay can only occur in non-stationary equilibria. Cai (2000), Cai (2003) shows that delay may also occur in Markov perfect equilibria: The more sellers are involved, the more serious is the delay until even a total breakdown of negotiations is possible.

The remainder of the chapter is organized as follows. In the next subsection, we demonstrate in a concrete example that a breakdown of negotiations may occur even if only two farmers are present. After outlining the model in section 2, we analyze the two-seller case in section 3. In section 4, we extend the model to N farmers. Section 5 concludes.

1.1. An Example

In this section, we provide a simple example to demonstrate that a breakdown of negotiations may occur as the unique equilibrium outcome even if only two farmers are present. The two farmers each own one parcel of land worth $V_1 = V_2 = 0.4$ to them. A local airport wants to construct

[2] Among others, see Fudenberg, Levine, and Tirole (1985), Hart (1989) and Rubinstein (1985) for one-sided asymmetric information; Chatterjee and Samuelson (1987) and Fudenberg and Tirole (1983) for two-sided asymmetric information.

a new runway for which it needs to acquire both parcels. If the airport manages to do so, the new runway yields a profit of $S = 1$. Should the airport acquire just one piece of land, it has to pay the farmer, but cannot construct the runway. In that case, the airport's payoff is zero minus the amount paid to the first farmer.[3] Thus, from the perspective of the airport the parcels are perfect complements. All parties have a common discount factor $\delta \in (0, 1)$.

For the purpose of this example, we adopt the bargaining procedure used in Cai (2000): A fixed ordering of the farmers is given. At the beginning of the game, the airport makes an offer to farmer 1. If he does not accept the offer, he makes a counteroffer which the airport may accept or reject. If there is no agreement, the next period begins and the airport bargains with farmer 2 in a similar fashion. If there is no agreement with farmer 2, a new period begins and the airport bargains with farmer 1 and so on. Once the airport has reached an agreement with one of the farmers, it and the remaining farmer bargain in an alternating offer fashion with the airport making the first offer. The payoffs are discounted once after each period.

Suppose the airport has agreed with farmer 1. Then, the airport and farmer 2 bargain over a pie of size $S - V_2 = 0.6$. Note that this pie is larger than the overall (net) social surplus of the project $S - V_1 - V_2 = 0.2$. This is so because the amount paid to farmer 1 is sunk. From Rubinstein (1982) we know that this subgame has a unique subgame-perfect Nash equilibrium (SPNE). In this SPNE, the airport gets an ex-post surplus (given that the price paid for the first parcel is sunk) of $\frac{S-V_2}{1+\delta}$. The airport's willingness to pay for farmer 1's parcel is equal to the discounted ex-post surplus $\frac{0.6\delta}{1+\delta}$. This amount is less than 0.4 for any $\delta \in [0, 1]$. Thus, the airport's willingness to pay for the first parcel is less than farmer 1's reservation value V_1. Therefore, a breakdown must constitute the unique equilibrium outcome. The equilibrium strategies are, however,

[3] In the model we relax the assumption that the airport's valuation of a parcel is zero should it acquire only one of the parcels.

not unique: The airport may offer a farmer any amount strictly below 0.4 which the farmer then rejects. The farmers may propose any amount greater than the airport's willingness to pay, which is in turn rejected by the airport.

The crucial driving factors behind our breakdown result are that the airport's stand-alone valuation for the parcels is lower than the farmers' and that the last remaining farmer gets a significant share of the bargaining cake. As we will see in the next sections, the exact structure of the bargaining game does, in contrast, not drive our result.

2. The Model

We consider a model with $N + 1$ risk-neutral parties, one buyer and N sellers. As a leading example, the buyer is an airport that needs to acquire the farmers' (sellers') land to construct a new runway. Each farmer i owns exactly one piece of land, which he valuates $V_i > 0$. Let us denote the sum of these valuations by $V := \sum_{i=1}^{N} V_i$. The airport's valuation depends on whether it manages to acquire all parcels or not. If it does, it constructs the runway which it valuates $S > V$. Thus, the construction is socially desirable. If the airport does not manage to acquire all parcels, it is not able to construct the runway. In that case, each parcel i is worth $V_i^A \geq 0$ to the airport. One may think of $V_i^A \geq 0$ as the market price of the parcel. Alternatively, it may represent the airport's profit if it uses the parcel for some other purpose. Let us denote the sum of these valuations by $V^A := \sum_{i=1}^{N} V_i^A$ and assume that $V_i > V_i^A \ \forall \ i = 1, ..., N$. Thus, for any given parcel the farmer's stand-alone valuation is greater than the airport's. The parties' discount factors are denoted $\Delta = \{\delta_A, \delta_1, ...\delta_N\} \in [0, 1]^{N+1}$, where δ_A represents the airport's discount factor. We assume that the parcels yield a constant flow of same period utilities, i.e., $(1 - \delta_i)V_i$ and $(1 - \delta_A)V_i^A$ for farmer i and the airport, respectively. Throughout the chapter, we assume that everything is common knowledge.

In the previous literature, see e.g. Cai (2000), the farmers' and the airport's stand-alone valuations V_i, V_i^A are normalized to zero. As we will see, that we do not adopt this normalization, but assume that the farmers' stand-alone valuations exceed the airport's is the main driving factor behind our breakdown result. Because we do not want to establish our result in a specific game only, we are going to show that it holds in a large class of discrete-time bargaining games. To do so, let us be more precise about the class of games we consider:

General Bargaining Game.— A general bargaining game, in our sense, consists of finitely or infinitely many periods. Each period consists of finitely or infinitely many rounds. The parties discount after each but not within a period. In any given round, some or all of the players may perform exactly one action. Depending on the game under consideration, the following actions may or may not be possible in any given round: The airport may make binding cash-offers to one or to several farmers simultaneously. Or one of the farmers may offer to sell his land to the airport. We also allow bargaining games where the party that can make offers in a given round is determined randomly. If a party gets an offer, it must decide in the round thereafter to either accept or reject it. If this party agrees, the airport immediately receives the farmer's parcel but has to pay the agreed upon price B_i to the farmer, who then leaves the game. We do not consider contingent contracts. Thus, the airport may not offer farmer i some price it only has to pay if it reaches an agreement with the remaining farmers. If at the beginning of some round only two parties, the airport and one farmer, are left in the game, we assume the following:

> **Assumption 1** If at the beginning of any given round only the airport and exactly one farmer are left in the game, the airport and the farmer play Rubinstein's (1982) simple alternating offers game with the airport making the first offer. Any unanswered offer is

void and the game continues until the Rubinstein game is finished.

Assumption 1 ensures that the last remaining farmer gets some positive fraction of the total bargaining cake. Thus, we implicitly rule out that the airport can make a take-it-or-leave-it offer to this farmer. Assumption 1 also states that offers may be void and thus remain unanswered. That occurs if only two parties are left in the game and one of them still has an offer on the table. Then, these parties play the Rubinstein game. It is important to emphasize that neither this assumption nor the fact that the airport makes the first offer in the Rubinstein game drives our main result. In the next section, we explain the parties' payoffs in detail. As an illustration, let us consider some examples that are in the class of games we consider:

(1) *The fixed bargaining procedure:* At the beginning of the game, a fixed ordering of farmers is given. Starting from the first farmer, the airport negotiates with the farmers in an alternating offer fashion as in Rubinstein (1982). The airport moves only to the next farmer if it has reached an agreement with the previous farmer.

This procedure can also be seen as a sequence of alternating offer games. It is an infinite horizon bargaining game in which each period consists of exactly two rounds. In the first round, an offer is made and in the second round it is either accepted or rejected.

(2) *The circular bargaining procedure:* This is the procedure used in Cai (2000). It is related to the fixed bargaining procedure. However, the sequence of agreements is determined endogenously. The farmers are ordered in a circle. Starting from the first farmer, the airport bargains with one farmer over a price in an alternating offer fashion. Each period starts with an offer by the airport, which the farmer then accepts or rejects. If he rejects, he makes a counteroffer in the next period which in turn the airport accepts or rejects. Once an agreement is reached, the

airport pays the agreed price right away and the farmer leaves the circle permanently. If the airport rejects the farmer's counteroffer, it then bargains with the next farmer in a similar fashion. After negotiating with the last farmer, the airport bargains with all farmers still in the game in the same order as before.

Cai's (2000) definition of a round differs from ours. What he denotes as a round is the span of time the airport negotiates with one farmer before it moves to the next. In the language of the present chapter, each period of the circular bargaining procedure consists of exactly two rounds. That is so because the parties do not discount after an offer has been made but only after it has been accepted or rejected.

(3) *"Weird" bargaining procedure:* If at any point in time only the airport and one farmer are left in the game, they play the Rubinstein game. The game begins with the airport making simultaneous offers to all farmers which they may accept or reject. Then, unless all or all but one farmer accepted the airport's offer, in the second period one randomly determined farmer makes an offer to the airport which it may either accept or reject. In the third period, no player has an action. In the fourth period, the airport makes simultaneous offers to all remaining farmers which they accept or reject. If more than one farmer rejects, the game ends. If one farmer rejects, the remaining farmer and the airport play the Rubinstein game starting from the fifth period.

Of course, this bargaining procedure is constructed arbitrarily. We provide it to illustrate that we do indeed consider a large class of bargaining games. As mentioned, to establish our main result it will turn out to be crucial that the last farmer still in the game can ensure himself some positive share of the ex-post bargaining surplus. To ensure that he can do so, we assumed that he and the airport play the Rubinstein game. Note that the Rubinstein game always takes precedence. To illustrate this point, consider a simple one period game where the airport makes simultaneous offers to all farmers which they accept or reject.

This game lasts only one period unless exactly one farmer rejects. In that case this farmer and the airport play the Rubinstein game and the total bargaining game is played at least two periods.

3. The two-Seller Case

In this section, we demonstrate that even if only two farmers are present a breakdown of negotiations may be the unique equilibrium outcome. Recall that if at the beginning of some round only two parties, one farmer and the airport, are left in the game, they play the Rubinstein game. Let us denote the farmers' Rubinstein payoffs by

$$
\begin{aligned}
R_1 &:= \left[\frac{\delta_1(1-\delta_A)(S-V_1-V_2^A)}{1-\delta_A\delta_1}+V_1\right] \quad \textit{and} \\
R_2 &:= \left[\frac{\delta_2(1-\delta_A)(S-V_2-V_1^A)}{1-\delta_A\delta_2}+V_2\right] \qquad \text{(III.1)}
\end{aligned}
$$

, respectively. The first line of (III.1) represents farmer 1's Rubinstein payoff in a situation where he is the last farmer in the game. Recall that the outside option for the airport is V_2^A, i.e. to only use farmer 2's parcel which it acquired earlier. Likewise, farmer 1's outside option is V_1, i.e. to keep using his parcel. Thus $(S - V_1 - V_2^A)$ represents the total bargaining cake between the airport and farmer 1. Note also that any previous payment from the airport to farmer 2 is sunk and thus does not influence the outcome of the Rubinstein game. Without knowing how the bargaining game exactly looks like, we can still deduce that an agreement between the airport and the farmers can only be an equilibrium outcome if

(i) the airport and one farmer, say farmer 2, play the Rubinstein game and reach an agreement. Within the same period, but in some previous round, the airport reached an agreement with farmer 1. This agreement may have been reached because the airport accepted an offer from farmer 1 or because farmer 1 accepted an offer from the airport. Or

(ii) the airport and one farmer, say farmer 2, play the Rubinstein game and reach an agreement. In some previous period, the airport reached an agreement with farmer 1. This agreement may have been reached because the airport accepted an offer from farmer 1 or farmer 1 accepted an offer from the airport. Or

(iii) the airport makes simultaneous offers to farmer 1 and farmer 2 which they accept. Each farmer knows that had he not accepted, the next round would have been in the same period or

(iv) the airport makes simultaneous offers to farmer 1 and farmer 2 which they accept. Each farmer knows that had he not accepted, the next round would have been in a new period.

Recall that the parties do not discount between two rounds if these rounds are in the same period. Thus cases (i) and (ii), and (iii) and (iv) differ only in that the parties discount in cases (ii) and (iv) but not in (i) and (iii). If there exists an agreement equilibrium in any game that is in the class of games we consider, one of the four sub-histories described above must occur on the equilibrium path. To establish our breakdown result, it is therefore sufficient to prove that there exist parameters (S, V_1, V_2) such that none of these sub-histories may occur on the equilibrium path. Of course, a breakdown result is only of interest if the construction of the runway is socially desirable. Thus, recall that we assumed $S > V_1 + V_2 > V_1^A + V_2^A$. We prove the following proposition:

Proposition III.1: *For any discount factors $\delta_A \in (0,1)$ and $(\delta_1, \delta_2) \in (0,1) \times (0,1)$ and for any valuations $(V_1, V_2) \in (0,\infty) \times (0,\infty)$ and $(V_1^A, V_2^A) \in [0, V_1) \times [0, V_2)$ there exists a project value $S > V_1 + V_2$ such that a breakdown of negotiations constitutes the unique equilibrium outcome in any general bargaining game.*

Proof.

The proof is structured as follows. First, we derive in each of the four cases a necessary condition for trade to be desirable for all parties. If it does not hold, at least one of the parties has an incentive to deviate and thus this case or sub-history cannot occur on the equilibrium path. Second, we show that there exist parameter constellations under which trade is socially desirable but none of the conditions holds. Thus, a breakdown must be the unique equilibrium outcome.

(i) If there exists an agreement equilibrium, the airport and farmer 2 reach a Rubinstein agreement. Thus, the airport pays R_2 to farmer 2. In some previous round but in the same period, the airport has to pay at least V_1 to farmer 1. Of course, the airport anticipates that should it reach an agreement with farmer 1, it has to pay R_2 to farmer 2. Thus an agreement can only be profitable for the airport if

$$V_1 + R_2 \leq S.^4 \qquad \text{(Condition 1)}$$

(ii) This case is similar to case (i). The only difference is that the Rubinstein game between the airport and farmer 2 begins in a new period. Thus, the amount the airport has to pay to farmer 1 is relatively more important and an agreement can only be profitable for the airport if

$$V_1 + \delta_A R_2 \leq \delta_A S + (1 - \delta_A) V_1^A \qquad \text{(III.2)}$$

where $(1 - \delta_A) V_1^A$ represents that the airport can use farmer 1's parcel for one more period. Let us rewrite (III.2) as

$$\frac{V_1 - (1 - \delta_A) V_1^A}{\delta_A} + R_2 \leq S. \qquad \text{(Condition 2)}$$

Note that if Condition 1 does not hold, it directly follows that Condition 2 does not hold either.

[4]Condition 1 is not a sufficient but a necessary condition for an agreement to be profitable for the airport. Depending on the game, the airport may have to pay farmer 1 more than V_1 for his parcel.

(iii) In this case the airport makes a simultaneous offer to both farmers which they accept. Should one of the farmers reject the airport's offer, he can ensure himself the Rubinstein outcome which he receives in the next round. Thus, to prevent that the farmers have an incentive to deviate, the airport has to offer them at least their potential Rubinstein payoffs R_1 and R_2. An agreement can therefore only be profitable for the airport if

$$R_1 + R_2 \leq S. \qquad \text{(Condition 3)}$$

(iv) This case is similar to case (iii). The only difference is that should a farmer reject the airport's offer, the Rubinstein game begins not in the same, but in the next period. Thus, in any agreement equilibrium, the airport has to pay at least

$$(1 - \delta_1)V_1 + \delta_1 R_1 + (1 - \delta_2)V_2 + \delta_2 R_2$$

where $(1 - \delta_1)V_1$ and $(1 - \delta_2)V_2$ represent that should a farmer refuse the airport's offer he can use his land for one more period. Trade is only profitable for the airport if

$$(1 - \delta_1)V_1 + \delta_1 R_1 + (1 - \delta_2)V_2 + \delta_2 R_2 \leq S. \qquad \text{(Condition 4)}$$

Note that if Condition 4 does not hold, Condition 3 does not either. In principle, the farmers could also use mixed strategies when the airport makes a simultaneous offer. In the appendix we demonstrate that if none of the four conditions holds a breakdown of negotiations must be the unique equilibrium outcome even if the parties can use mixed strategies. Let us now show that there exist parameter constellations under which trade is socially desirable but none of the conditions holds. This is the case if

$$\min[V_1 + R_2, V_2 + R_1, (1 - \delta_1)V_1 + \delta_1 R_1 + (1 - \delta_2)V_2 + \delta_2 R_2] > S. \qquad \text{(III.3)}$$

It is clear that if (III.3) holds, trade cannot take place sequentially and simultaneously. Of course, a breakdown result is not surprising if trade is socially not desirable. However, for any discount factors $\delta_A \in (0,1)$ and $(\delta_1, \delta_2) \in (0,1) \times (0,1)$, there exists some $S > V_1 + V_2$ that is smaller than the left hand side of (III.3). To see that this is so, note that (δ_1, δ_2) $\in (0,1] \times (0,1]$ implies $R_1 > V_1$ and $R_2 > V_2$. ■

Intuitively, two important factors drive our result. First, that we did not normalize, as e.g. in Cai (2000), the farmers' stand-alone utility to zero and second that the parcels are complements in the sense that the full benefit only accrues to the airport if it acquires both parcels. Consider a situation where the airport acquired the parcel from farmer 1 and is bargaining with farmer 2. The price paid to farmer 1 is sunk and therefore does not affect the outcome of the Rubinstein game between the airport and farmer 2. Hence, there exist situations where the sum of the price paid to farmer 1 plus farmer 2's Rubinstein share is higher than the value of the airport's project S. Anticipating this and knowing that farmer 1 does not accept any price below his reservation utility V_1, the airport may not be willing to reach an agreement with farmer 1. A breakdown equilibrium may also exist in games where the airport makes simultaneous offers to both farmers. To ensure that neither farmer has an incentive to reject the airport's offer, the airport has to offer them at least their Rubinstein payoffs. This is so because given that, say, farmer 1 accepts the airport's offer, farmer 2 is in a strong position. He knows that should he reject the airport's offer, he will play a Rubinstein game with the airport. It is clear that a breakdown may occur because the airport may not be able to pay both farmers their respective Rubinstein payoffs.

Surprisingly, a breakdown may also occur if the airport is patient, i.e., its discount factor is high and the farmers' are low. From the proof, we can deduce that this can only be the case if the value of the airport's project S is close to the sum of the reservation utilities of the farmers, $V_1 + V_2$. Thus, a breakdown equilibrium is more likely to exist if the gap between S and $V_1 + V_2$ is small and if the farmers are patient relative to the airport. The latter statement stems from the fact that a patient farmer can ensure himself a larger Rubinstein payoff. Recall that the class of bargaining games contains games where, as long as both farmers are still in the game, the parties discount but also games where they do not discount. From the proof we can deduce that in the sequential case a breakdown equilibrium is more likely to exist if the parties play a game where they do discount. This is so because the amount the airport pays to the first farmer is relatively more important compared to the value of the project, S, that accrues to it one period later. In contrast, in the simultaneous case a breakdown is less likely if the parties discount. Recall that the airport has to offer each farmer at least his respective Rubinstein surplus. This amount is lower if a new period begins after the airport's offer compared to situations where if the Rubinstein game occurs it does so in the same period.

In the next section, we extend our model to the N-farmer case. We demonstrate that if sufficiently many farmers are present, a breakdown may constitute the unique equilibrium outcome even if the airport is patient relative to the farmers and if the value of the airport's project is very high compared to the sum of the farmers' reservation utilities.

4. The N-Farmer Case

Let us explore how our model can be extended to the N-farmer case. It is straightforward that our breakdown result can also be established if more than two farmers are present. As before, at least one of the farmers gets more than his reservation utility. Hence, a breakdown of negotiations is the unique equilibrium outcome for a sufficiently low value of S. Recall also that it is a well-known result of the literature, see e.g. Cai (2000), that a breakdown equilibrium is more likely to exist if more farmers are present.[5] In this section, we use the fixed bargaining procedure as a

[5] In Cai (2000), a breakdown of negotiations can only occur if at least four farmers are present.

concrete example. As we will see, a breakdown constitutes the unique equilibrium outcome even if the airport is patient relative to the farmers and if the value of the airport's project is high compared to the sum of the farmers' reservation utilities.

Recall that under the fixed bargaining procedure a fixed ordering of farmers is given. Starting from the first farmer, the airport negotiates with the farmers in an alternating offer fashion as in Rubinstein (1982). The airport moves only to the next farmer if it has reached an agreement with the previous farmer. To be able to do comparative statics with respect to the number of farmers, we assume that they are symmetric: The farmers share a common discount factor $\delta_F \in (0,1)$. Furthermore, all parcels are worth $\frac{V}{N}$ to the farmers and $\frac{V^A}{N}$ to the airport. Note that we keep the sums of these stand-alone valuations constant: If more farmers are present, the value of each farmer's parcel decreases. Let us derive the solution by backwards induction: Given that the airport has reached an agreement with all farmers but the last (farmer N), the airport and farmer N bargain over a pie of size

$$\overbrace{S}^{\text{Joint surplus in case of trade}} - \underbrace{\left[\frac{(N-1)V^A}{N} + \frac{V}{N}\right]}_{\text{Joint surplus in case of no trade}} > 0.$$

Note that at this point all payments to the previous farmers (farmers $1, ..., N-1$) are sunk and thus do not affect the outcome of the Rubinstein game between the airport and farmer N. The airport's payoff from the negotiations with farmer N amounts to

$$\frac{(1-\delta_F)\left(S - \frac{V+(N-1)V^A}{N}\right)}{1-\delta_A\delta_F} + \frac{(N-1)V^A}{N}. \tag{III.4}$$

The airport and farmer $N-1$ anticipate that should they reach an agreement, (III.4) is the airport's ex-post payoff. They thus negotiate over a pie of size

$$\overbrace{\delta_A\left(\frac{(1-\delta_F)\left(S-\frac{V+(N-1)V^A}{N}\right)}{1-\delta_A\delta_F}+\frac{(N-1)V^A}{N}\right)+(1-\delta_A)\frac{V^A(N-1)}{N}}^{\text{Joint surplus in case of trade}}$$
$$-\underbrace{\left[\frac{(N-2)V^A}{N}+\frac{V}{N}\right]}_{\text{Joint surplus in case of no trade}}$$
$$=\delta_A\left(\frac{(1-\delta_F)\left(S-\frac{V+(N-1)V^A}{N}\right)}{1-\delta_A\delta_F}\right)-\frac{V-V^A}{N}. \qquad \text{(III.5)}$$

The term $(1-\delta_A)\frac{V^A(N-1)}{N}$ captures the one period utility the airport derives from all parcels it owns after an agreement with farmer $N-1$. Of course, (III.5) may, in principle, be negative. In that case, we can directly conclude that a breakdown of negotiation must constitute the unique equilibrium outcome. For trade to be an equilibrium outcome, the bargaining pie between the first farmer and the airport must be non-negative. If it is, it is straightforward that all following bargaining pies between the airport and the other farmers are non-negative, too. In the appendix we calculate the pie between the airport and farmer 1 and prove that

Lemma 1:

$$S \geq \frac{N-1}{N}V^A+\sum_{i=1}^{N}\frac{V-V^A}{N}\left(\frac{1-\delta_A\delta_F}{\delta_A(1-\delta_F)}\right)^{N-i} \qquad \text{(III.6)}$$

is a necessary condition for trade to occur. That (III.6) holds with strict inequality is sufficient for trade to occur.

Proof. See appendix. ■

Lemma 1 highlights a nice feature of the fixed bargaining procedure. Only if it holds with equality, both a breakdown and trade constitute an equilibrium outcome. Let us consider the impact of the number of farmers on the likeliness of a breakdown of negotiations. Recall that we keep the sum of the farmers' and the airport's stand-alone valuations constant as N grows.

If $\delta_A < 1$, the term $\frac{1-\delta_A\delta_F}{\delta_A(1-\delta_F)}$ is strictly greater than 1. Thus, the right-hand side goes to infinity as the number of farmers goes to infinity. We have established the following proposition:

Proposition III.2: *If all farmers are symmetric, for N sufficiently large a breakdown of negotiations constitutes the unique equilibrium outcome for any parameter constellation.*

The intuition behind Proposition III.2 is that each farmer receives a positive fraction of the residual bargaining cake. Because previous payments are sunk and not taken into account, the sum of these fractions may exceed the total bargaining cake. This effect is magnified the more farmers are present and thus a breakdown constitutes the unique equilibrium outcome for a sufficiently large number of farmers. That a breakdown may occur even for a very large social surplus $S - V$ may help to explain often observed real-world behavior. In land assembly problems, the social surplus is typically large, but the number of parties involved may be also.

In this section, we have only considered a particular game. To analyze the consequences of increasing the number of farmers in the entire class of general bargaining games defined in the previous section is extremely cumbersome if not unfeasible. It is apparent that a breakdown can never become less likely if more farmers are involved. If, however, a breakdown must occur even for a very large social surplus depends on the bargaining protocol under consideration. We conjecture that this is more likely to be the case in games where the parcels have to be obtained sequentially. As mentioned, the airport then loses money with each agreement.

5. Discussion

The aim of this chapter is to demonstrate that if the parties bargain over complements and the transactions are governed by binding cash-offer contracts, a breakdown of negotiations may often be the unique equilibrium outcome. We claim that this is true for a very large class of bargaining games. This class of games includes games where, as long as at least two farmers are still in the game, the parties may discount in certain periods and not discount in others. Yet, we assume that the parties play a Rubinstein game once only one farmer is left. Does this reduce the generality of our result? We claim that this is not so. For our result to hold it is important only that the last farmer still in the game can ensure himself more than his reservation utility. A counterexample in which he cannot do so are take-it-or-leave-it games. In these games, the airport has the full relative bargaining power and must offer both farmers their respective reservation utilities only.

Our assumption that a Rubinstein game is played once only two parties are left may lead to situations where an offer is still on the table. This offer then remains unanswered. Suppose we would have assumed that any offer has to be answered before the Rubinstein game is played. Then, the party that has to respond to the offer knows that a rejection directly leads to the Rubinstein game being played. Suppose a farmer is the one to respond. This farmer would not accept less than what he would get in the Rubinstein game. If the airport is the one to respond, the farmer anticipates that should the airport decline his offer the parties play the Rubinstein game. Consequently, the farmer demands at least his Rubinstein payoff. Thus our implicit assumption that offers may remain unanswered simplifies the analysis but does not drive our main result.

As a possible extension, we could also have allowed that the farmers may purchase land from each other. We believe that our breakdown result can also be established in such situations. In contrast to before, it is then the last remaining farmer whose earlier payments are sunk at the point in time he and the airport play the Rubinstein game. Thus, if the sum of these sunk payments is larger than the last remaining farmer's Rubinstein share, he makes a loss. Anticipating this, none of the farmers may have an incentive to buy the other farmers' parcels.

In the present chapter we have only explicitly considered binding cash-offer contracts. We believe, however, that our breakdown result can be generalized to more complex contractual settings. Consider, for example, the parties stipulated in contract that the airport has the right to sell back a parcel for some price that is below the farmer's stand-alone utility. This price can then be interpreted as the airport's stand-alone valuation of the parcel. Thus with the introduction of V_i^A we have covered many possibilities of what may happen if the airport acquires not all of the parcels: The airport may use the parcel, sell it on the market, or sell it to one of the farmers. For future research it is an interesting prospect to analyze whether our result holds if the parties can write even more complex contracts. A promising case to study may be option contracts where a parcel is only acquired and the farmer paid if the airport reaches an agreement with all farmers.

A. Appendices

1. Appendix to Chapter I

1.1. Threshold under Uninformed Creditor's Priority and $d_U > Y_L$

We know that for the equilibrium threshold $q_L^* = q_L^*(\alpha_U | d_U > Y_L)$, the following equation holds, where - in slight abuse of notation - $r_U^*(\alpha_U, q_L | d_U > Y_L)$ is the value of r_U that yields to zero profit for U given a threshold q_L:

$$
\begin{aligned}
& Y_H = r_I^*(\alpha_U, q_L^*, r_U^*, z_U^*) + r_U^*(\alpha_U, q_L^* | d_U > Y_L) \\
& = \frac{d_I}{q_L^*} + \frac{2d_U - (1 - q_L^*)Y_L}{1 + q_L^*} \\
\Leftrightarrow & (1 + q_L^*)q_L^* Y_H = (1 + q_L^*)d_I + 2q_L^* \left(d_U - \frac{1}{2}(1 - q_L^*)Y_L \right) \\
\Leftrightarrow & (q_L^* + {q_L^*}^2)Y_H = (1 + q_L^*)d_I + 2q_L^* d_U - (q_L^* - {q_L^*}^2)Y_L \\
\Leftrightarrow & 0 = {q_L^*}^2(Y_L - Y_H) - q_L^*[Y_H + Y_L - 2d_U - d_I] + d_I = 0 \\
\Leftrightarrow & 0 = {q_L^*}^2 + q_L^* \frac{Y_H + Y_L - d_U - D}{Y_H - Y_L} - \frac{d_I}{Y_H - Y_L} \\
\Leftrightarrow & q_L^* = -\frac{Y_H + Y_L - d_U - D}{2(Y_H - Y_L)} \pm \sqrt{\left[\frac{Y_H + Y_L - d_U - D}{2(Y_H - Y_L)} \right]^2 + \frac{d_I}{Y_H - Y_L}}.
\end{aligned}
$$

Note that we can exclude the −solution because then the solution for q_L^* would be negative.

$$q_L^* = -\frac{Y_H + Y_L - d_U - D}{2(Y_H - Y_L)} + \sqrt{\left[\frac{Y_H + Y_L - d_U - D}{2(Y_H - Y_L)}\right]^2 + \frac{4(Y_H - Y_L)d_I}{[2(Y_H - Y_L)]^2}}$$

$$\Leftrightarrow q_L^* = -\frac{Y_H + Y_L - d_U - D}{2(Y_H - Y_L)} + \frac{\sqrt{[Y_H + Y_L - d_U - D]^2 + 4d_I(Y_H - Y_L)}}{2(Y_H - Y_L)} \tag{I.11}$$

1.2. Threshold under the Pro-rata Rule

Recall that under the pro-rata rule the threshold $q_L^* = q_L(\alpha_P)$ up to which the informed creditor can finance the projects is a max-function with one argument being q^{SO}. Now, suppose the equilibrium threshold was indeed $q_L^* = q^{SO}$. In this case, we had:[1]

$$\begin{aligned} & r_I^*(\alpha_P, q_L, r_U^*, z_U^*) + r_U^*(\alpha_P, q_L^*) \\ &= \frac{d_I - (1 - q^{SO})d_I Y_L}{q^{SO}} + \frac{2d_U - (1 - q^{SO})d_U Y_L}{1 + q^{SO}} \\ &< \frac{d_I - (1 - q^{SO})d_I Y_L}{q^{SO}} + \frac{d_U - (1 - q^{SO})d_U Y_L}{q^{SO}} = Y_H, \end{aligned}$$

[1] Recall that $r_I^*(\alpha_P, q_L, r_U^*, z_U^*)$ is the value of r_I that yields zero profit for the informed creditor for q_L and $r_U^*(\alpha_P, q_L^*)$ is the value of r_U that leads to zero profit for the uninformed creditor given that all projects $q \geq q_L$ are carried out.

which means that this restriction cannot be binding. Hence, the other restriction must be binding, which yields:

$$
\begin{aligned}
Y_H &= r_I^*(\alpha_P, q_L^*, r_U^*, z_U^*) + r_U^*(\alpha_P, q_L^*) \qquad \text{(A.1)}\\
&= \frac{d_I - (1-q_L^*)Y_L d_I}{q_L^*} + \frac{2d_U - (1-q_L^*)d_U Y_L}{1+q_L^*}\\
\Leftrightarrow & q_L^*(1+q_L^*)Y_H = (1+q_L^*)[d_I - (1-q_L^*)Y_L d_I] + q_L^*[2d_U - (1-q_L^*)d_U Y_L]\\
\Leftrightarrow & {q_L^*}^2(Y_H - Y_L) + q_L^*(Y_H - d_I - 2d_U + d_U Y_L) + (Y_L d_I - d_I) = 0\\
\Leftrightarrow & q_L^* = -\frac{Y_H - 2d_U + Y_L d_U - d_I}{2(Y_H - Y_L)}\\
&\qquad \pm \sqrt{\left[\frac{Y_H - 2d_U + Y_L d_U - d_I}{2(Y_H - Y_L)}\right]^2 + \frac{d_I - d_I Y_L}{Y_H - Y_L}}
\end{aligned}
\qquad \text{(A.2)}
$$

Note that we can exclude the $-$-solution, because $d_I Y_L - d_I$ is smaller than zero. Hence:

$$
\begin{aligned}
\Leftrightarrow q_L^*(\alpha_P) &= \frac{Y_H - 2d_U + Y_L d_U - d_I}{2(Y_H - Y_L)}\\
&\pm \sqrt{\left[\frac{Y_H - 2d_U + Y_L d_U - d_I}{2(Y_H - Y_L)}\right]^2 + \frac{d_I - d_I Y_L}{Y_H - Y_L}}
\end{aligned}
\qquad \text{(I.16)}
$$

As $D - Y_L > 0$ holds, there must be a real solution. Therefore, the absolute value of the root is smaller than the absolute value of the first summand.

1.3. Proof of Proposition I.7

We have to show that under any rule, the threshold is weakly lower than the socially efficient one. Under U's priority and when even the low state cash flow is sufficient to repay his loan, we have found the result to be first best. Under informed creditor's priority the threshold is either 0 or $\frac{d_I - Y_L}{Y_H - Y_L}$, which is strictly lower than the socially efficient threshold.

For the two remaining cases (uninformed creditor's priority with $d_U > Y_L$ and pro-rata rule), recall that $r_I^*(\alpha, q_L) = r_I^*(\alpha, q_L, r_U, z_U), r_U^*(\alpha, q_L)$

denote the values of r_I, r_U such that the creditors make zero profit in expectation given a threshold q_L. We know that $r_I^*(\alpha, q_L^*) + r_U^*(\alpha, q_L^*) = Y_H$ holds for the equilibrium threshold. Furthermore, we know that both $r_I^*(\alpha, q_L)$ and $r_U^*(\alpha, q_L)$ are strictly monotonically decreasing in q_L. We can conclude that whenever the sum of the repayment claims exceeds Y_H for a given q_L, the threshold in equilibrium must be higher, and, in turn, if the sum of the repayment claims falls short of Y_H, the threshold must be lower.

Now, suppose, the socially efficient threshold was the equilibrium threshold, $q_L = q^{SO}$:

Under uninformed creditor's priority and $d_U > Y_L$ we have:

$$r_I^*(\alpha_U, q^{SO}) + r_U^*(\alpha_U, q^{SO}) = \frac{d_I}{q^{SO}} + \frac{2d_U - \left(1 - q^{SO}\right) Y_L}{1 + q^{SO}}$$
$$= \frac{d_I}{q^{SO}} + \frac{2d_U - 2\left(1 - q^{SO}\right) Y_L}{1 + q^{SO}} + Y_L < \frac{d_I}{q^{SO}} + \frac{d_U - Y_L + q^{SO} Y_L}{q^{SO}} + Y_L$$
$$< \frac{d_I}{q^{SO}} + \frac{d_U - Y_L}{q^{SO}} + Y_L = \frac{(D - Y_L)(Y_H - Y_L)}{D - Y_L} + Y_L = Y_H,$$

and for the pro-rata rule:

$$r_I^*(\alpha_P, q^{SO}) + r_U^*(\alpha_P, q^{SO}) = \frac{d_I - (1 - q^{SO}) d_I Y_L}{q^{SO}} + \frac{2d_U - (1 - q^{SO}) d_U Y_L}{1 + q^{SO}}$$
$$< d_I \frac{1 - (1 - q^{SO}) Y_L}{q^{SO}} + d_U \frac{1 - (1 - q^{SO}) Y_L}{q^{SO}}$$
$$= \frac{1 - (1 - q^{SO}) Y_L}{q^{SO}} = \frac{(D - Y_L)(Y_H - Y_L)}{D - Y_L} + Y_L = Y_H$$

Hence, at the socially efficient threshold $r_I^*(\alpha, q^{SO}) + r_U^*(\alpha, q^{SO}) < Y_H$ holds for both rules. Hence, the threshold must be lower in equilibrium, which proves the claim.

1.4. Proof of Proposition I.8

First of all, from above we know that under U's priority and $d_U \leq Y_L$, the threshold must be highest. Under informed creditor's priority and $d_I \leq Y_L$, all projects may be realized, which implies that the threshold is lowest.

If $d_I > Y_L$, the cutoff value under informed creditor's priority is given by $q_L^*(\alpha_I | d_I > Y_L) = \frac{d_I - Y_L}{Y_H - Y_L}$. Now suppose, this was the cutoff value in case of the pro-rata rule:[2]

$$\begin{aligned} & r_I^*(\alpha_P, q_L^*(\alpha_I | d_I > Y_L)) + r_U^*(\alpha_P, q_L^*(\alpha_I | d_I > Y_L)) \\ &= \frac{d_I - (1 - q_L)Y_L}{q_L} + \frac{d_U}{\frac{1+q_L}{2}} = \frac{(d_I - Y_L)(Y_H - Y_L)}{Y_H - Y_L} + Y_L + \frac{d_U}{\frac{1+q_L}{2}} > Y_H, \end{aligned}$$

which implies that the threshold under the pro-rata rule is higher than under informed creditor's priority.

To compare the pro-rata rule with uninformed creditor's priority with $d_U > Y_L$, recall the condition for the equilibrium threshold under the pro-rata rule:

$$\begin{aligned} Y_H &= r_I^*(\alpha_P, q_L^*(\alpha_P), r_U^*, z_U^*) + r_U^*(\alpha_P, q_L^*(\alpha_P)) \qquad \text{(A.1)} \\ &= \frac{d_I - (1 - q_L^*(\alpha_P))Y_L d_I}{q_L^*(\alpha_P)} + \frac{2d_U - (1 - q_L^*(\alpha_P))d_U Y_L}{1 + q_L^*(\alpha_P)} \\ &= d_I \frac{1 - (1 - q_L^*(\alpha_P))Y_L}{q_L^*(\alpha_P)} + d_U \frac{1 - (1 - \frac{1+q_L^*(\alpha_P)}{2})Y_L}{\frac{1+q_L^*(\alpha_P)}{2}} \\ &= \frac{d_I}{q_L^*(\alpha_P)} - \frac{d_I Y_L}{q_L^*(\alpha_P)} + \frac{d_U}{\frac{1+q_L^*(\alpha_P)}{2}} - \frac{d_U Y_L}{\frac{1+q_L^*(\alpha_P)}{2}} + Y_L \\ &\leq \frac{d_I}{q_L^*(\alpha_P)} - \frac{d_I Y_L}{\frac{1+q_L^*(\alpha_P)}{2}} + \frac{d_U}{\frac{1+q_L^*(\alpha_P)}{2}} - \frac{d_U Y_L}{\frac{1+q_L^*(\alpha_P)}{2}} + Y_L \\ &= \frac{d_I}{q_L^*(\alpha_P)} - \frac{d_I - (1 - \frac{1+q_L^*(\alpha_P)}{2})Y_L}{\frac{1+q_L^*(\alpha_P)}{2}} \\ &= r_I^*(\alpha_U, q_L^*(\alpha_P), r_U^*, z_U^*) + r_U^*(\alpha_U, q_L^*(\alpha_P)) \qquad \text{(A.3)} \end{aligned}$$

[2]Recall that $r_I^*(\alpha, q_L) = r_I^*(\alpha, q_L, r_U, z_U), r_U^*(\alpha, q_L)$ denote the values of r_I, r_U such that the creditors make zero profit in expectation.

Note that the inequality holds strictly whenever $Y_L > 0$. If $Y_L = 0$, the thresholds are equal. Expression (A.3) is the hypothetical sum under uninformed creditor's priority for the threshold in the pro-rata case. We can see that Y_H falls short of this sum whenever $Y_L > 0$, which indicates that under uninformed creditor's priority, the threshold must be higher. If $Y_L = 0$ holds, however, the thresholds under uninformed creditor's priority with $d_U > Y_L$ and the pro-rata rule are equal.

1.5. Threshold under Equity Financing

We know that for the equilibrium threshold $q_L^* = q_L^*(\alpha_E)$ both (I.24) and (I.21) have to be fulfilled. Reorganizing of (I.23) yields:

$$\frac{1+q_L^*}{2} x_U^* Y_H + \frac{1-q_L^*}{2} x_U^* Y_L = d_U$$
$$\Leftrightarrow x_U^*[q_L^* Y_H + (1-q_L^*)Y_L] = 2d_U - x_U^* Y_H.$$

Substituting for x_U^* (see (I.20)) yields

$$q_L^* Y_H + (1-q_L^*)Y_L - d_I = 2d_U - Y_H \left[1 - \frac{d_I}{q_L^* Y_H + (1-q_L^*)Y_L}\right]$$
$$\Leftrightarrow Y_H - \frac{Y_H - d_I}{q_L^* Y_H + (1-q_L^*)Y_L} + q_L^* Y_H + (1-q_L^*)Y_L = D + d_U$$

Now, let us substitute $q_L^* Y_H + (1-q_L^*)Y_L$ by $E[Y|q_L^*]$:

$$Y_H E[Y|q_L^*] - Y_H d_I + E^2[Y|q_L^*] = E[Y|q_L^*](D + d_U)$$
$$\Leftrightarrow E[Y|q_L^*] = \frac{D + d_U - Y_H}{2} \pm \sqrt{\frac{1}{4}(D + d_U - Y_H)^2 + Y_H d_I}.$$

Note that we can exclude the $-$solution because this would yield a negative value for $E[Y|q_L^*]$. Re-substituting yields

$$q_L^* Y_H + (1-q_L^*)Y_L = \frac{D + d_U - Y_H}{2} + \sqrt{\frac{1}{4}(D + d_U - Y_H)^2 + Y_H d_I}$$
$$\Leftrightarrow q_L^*(\alpha_E) = \frac{\frac{1}{2}(D + d_U - Y_H) + \sqrt{\frac{1}{4}(D + d_U - Y_H)^2 + Y_H d_I} - Y_L}{Y_H - Y_L} \tag{I.25}$$

1.6. Proof of Proposition I.10

In order to establish the proposition, we have to show that the threshold in case of equity financing is higher than under informed creditor's priority, but lower than under the pro-rata rule.

The first part of the claim is quite easily shown. We know from above that under equity financing $q_L^*(\alpha_E) > 0$. Thus, we only need to consider the case with $d_I > Y_L$. If the threshold under equity financing were then equal to $\frac{d_I - Y_L}{Y_H - Y_L}$, the sum of the shares would be:[3]

$$\begin{aligned} & x_I^* \left(\alpha_E, q_L = \frac{d_I - Y_L}{Y_H - Y_L}, x_U^*, z_U^* \right) + x_U^* \left(\alpha_E, q_L = \frac{d_I - Y_L}{Y_H - Y_L} \right) \\ & = \frac{d_I}{Y_H \frac{d_I - Y_L}{Y_H - Y_L} + Y_L (1 - \frac{d_I - Y_L}{Y_H - Y_L})} + \frac{d_U}{Y_H \frac{Y_H + d_I - 2Y_L}{2(Y_H - Y_L)} + Y_L \frac{Y_H - d_I}{2(Y_H - Y_L)}} \\ & > \frac{d_I (Y_H - Y_L)}{Y_H (d_I - Y_L) + Y_L (Y_H - d_I)} = \frac{d_I (Y_H - Y_L)}{Y_H d_I - Y_L d_I} = 1 \end{aligned}$$

As both x_I^* and x_U^* are strictly decreasing in q_L, the equilibrium threshold must be higher. Hence, under equity financing less projects may get started than under informed creditor's priority.

In the second step, let us compare the thresholds of the pro-rata rule and equity financing. Here, we employ a slightly different method: We calculate the expected payment to the uninformed creditor in case of the pro-rata rule and show that this is more than what the entrepreneur pays in expectation to the uninformed creditor. From this we can conclude that the coalition of the informed creditor and the entrepreneur can finance even worse projects under equity financing than under the pro-rata rule.

The expected payment in case of the pro-rata rule is given by:

[3] Recall that $x_I^*(\alpha_E, q_L, r_U, z_U), x_U^*(\alpha_E, q_L)$ denote the values of r_I, r_U such that the creditors make zero profit in expectation given a threshold q_L.

$$
\begin{aligned}
& q_L^*(\alpha_P) r_U^*(\alpha_P) + (1 - q_L^*(\alpha_P)) d_U Y_L \\
& = d_U \left[q_L^*(\alpha_P) \frac{2 - (1 - q_L^*(\alpha_P)) Y_L}{1 + q_L^*(\alpha_P)} + (1 - q_L^*(\alpha_P)) Y_L \right] \\
& = d_U \left[\frac{2 q_L^*(\alpha_P) + (1 - q_L^*(\alpha_P)) Y_L}{1 + q_L^*(\alpha_P)} \right] \\
& = d_U \left[\frac{2 + 2 q_L^*(\alpha_P) + (1 - q_L^*(\alpha_P)) Y_L - 2}{1 + q_L^*(\alpha_P)} \right] \\
& = d_U \left[2 - \frac{2 - 2Y_L - (1 - q_L^*(\alpha_P) - 2) Y_L}{1 + q_L^*(\alpha_P)} \right] \\
& = d_U \left[2 - \frac{2 - 2Y_L}{1 + q_L^*(\alpha_P)} - Y_L \right] \\
& \geq d_U \left[2 - \frac{2Y_H}{(1 + q_L^*(\alpha_P)) Y_H + (1 - q_L^*(\alpha_P)) Y_L} \right] \\
& = q_L^*(\alpha_P) Y_H \frac{2 d_U}{(1 + q_L^*(\alpha_P)) Y_H + (1 - q_L^*(\alpha_P))) Y_L} \\
& + (1 - q_L^*(\alpha_P)) Y_L \frac{2 d_U}{(1 + q_L^*(\alpha_P)) Y_H + (1 - q_L^*(\alpha_P))) Y_L},
\end{aligned}
$$

which is the hypothetical expected payment to the uninformed creditor in case of equity financing if $q_L^*(\alpha_P)$ was the threshold. This implies that the equilibrium threshold under equity financing is lower than under the pro-rata rule. Note that the expression in the braced part must be greater than zero, because otherwise all projects in average would yield a loss, which would imply that the uninformed creditor would never grant a credit.

2. Appendix to Chapter II

2.1. Comparison between private and efficient investment

Proof. Let us compare the landowner's privately optimal investment level in absence of the risk of a taking with the socially best response to the government's investment in the general case where a taking may occur. We prove that e_L^p is, for any investment of the government, at least as high as any $e_L \in e_L^{SBR}(e_G)$. In absence of the risk of a taking, the landowner's optimal investment maximizes

$$e_L^p \in \arg\max_{e \in [0, e_L^{max}]} E[U_L^p(e_L, \omega, q)] = E[V(e_L, \omega)] - e_L.$$

Take any $e_G \in [0, e_G^{max}]$ and note that

$$E[U_L^p(e_L, \omega, q)] - E[W(e_L, e_G, \omega, q^*(e_L, e_G, \omega))] = \\ E[min[V(e_L, \omega) - S(e_G, \omega), 0] + e_G$$

is increasing in e_L due to Assumption 2. Let us denote the greatest element of $e_L^{SBR}(e_G)$ by $e_L^{max}(e_G)$. Take any $e_L < e_L^{max}(e_G)$ that is not a socially best response itself. Then it must hold that

$$E[U_L^p(e_L, \omega, q)] - E[W(e_L, e_G, \omega, q^*(e_L, e_G, \omega))] \leq \\ E[U_L^p(e_L^{max}(e_G), \omega, q)] - E[W(e_L^{max}(e_G), e_G, \omega, q^*(e_L^{max}(e_G), e_G, \omega))].$$

Because

$$E[W(e_L^{max}(e_G), e_G, \omega, q^*(e_L^{max}(e_G), e_G, \omega))] > E[W(e_L, e_G, \omega, q^*(e_L, e_G, \omega))]$$

it must hold that

$$E[U_L^p(e_L, \omega, q)] < E[U_L^p(e_L^{max}(e_G)\omega, q)]$$

and consequently $e_L^p \geq e_L^{max}(e_G)$. ■

Note that this directly implies $e_L^p \geq e_L^*$. In a similar way one can show that the government's privately optimal investment level exceeds the socially best response to any investment of the landowner. This directly implies $e_G^p \geq e_G^*$.

2.2. Proof of Theorem II.1

Proof. Let us prove that the landowner's investment incentives, under the compensation regimes considered in Section 3, can be ranked in the following way:

$$\forall e_L \in e_L^{SBC} : e_L^{FC} = e_L^p \geq e_L \geq e_L^{SOPVC} = e_L^* \geq e_L^{NC} = 0. \quad \text{(II.3)}$$

In Appendix 2.1, it was explained that e_L^p is, for any e_G, at least as high as the greatest element of $e_L^{SBR}(e_G)$. Because $e_L^{FC} = e_L^p$ and the landowner's best response under the social benefit compensation regime is equivalent to the social best response, the first claim directly follows. Let us establish that *any* $e_L \in e_L^{SBC} \geq e_L^{SOPVC} = e_L^*$. To do so, consider the difference between the landowner's expected payoff under the social benefit compensation regime and expected social surplus. It is given by

$$\begin{aligned}
&E[U_L^{SBC}(e_L, 0, \omega, q^*(e_L, 0, \omega))] - E[W(e_L, e_G^*, \omega, q^*(e_L, e_G^*, \omega))] = \\
&E[W(e_L, 0, \omega, q^*(e_L, 0, \omega))] - E[W(e_L, e_G^*, \omega, q^*(e_L, e_G^*, \omega))] = \\
&E[min[max[V(e_L, \omega), S(0, \omega)] - S(e_G^*, \omega), 0]]
\end{aligned}$$

which is increasing in e_L due to Assumption 2. Note that we used that the government invests zero under the SBC regime and that the socially best response to e_L^* is e_G^*. Take any $e_L < e_L^*$, then

$$\begin{aligned}
&E[U_L^{SBC}(e_L, 0, \omega, q^*(e_L, 0, \omega))] - E[W(e_L, e_G^*, \omega, q^*(e_L, e_G^*, \omega))] \leq \\
&E[U_L^{SBC}(e_L^*, 0, \omega, q^*(e_L^*, 0, \omega))] - E[W(e_L^*, e_G^*, \omega, q^*(e_L^*, e_G^*, \omega))].
\end{aligned}$$

Because expected welfare is uniquely maximized by (e_L^*, e_G^*), this implies

$$E[U_L^{SBC}(e_L, 0, \omega, q^*(e_L, 0, \omega))] < E[U_L^{SBC}(e_L^*, 0, \omega, q^*(e_L^*, 0, \omega))]$$

and consequently *any* $e_L \in e_L^{SBC} \geq e_L^{SOPVC} = e_L^*$. Since $e_L^{NC} = 0$, it is clear that $e_L^{SOPVC} > e_L^{NC}$. Similarly, we can rank the government's investment incentives:

$$\forall e_G \in e_G^{FC} : e_G^{NC} = e_G^p \geq e_G^{SOPVC} = e_G^* \geq e_G \geq e_G^{SBC} = 0. \quad \text{(II.4)}$$

In Appendix 2.1, it was explained that $e_G^p \geq e_G^*$. Because $e_G^{NC} = e_G^p$ and $e_G^{SOPVC} = e_G^*$, it directly follows that $e_G^{NC} \geq e_G^{SOPVC}$. The proof that e_L^{SOPVC} is at least as high as *any* $e_G \in e_G^{FC}$ can be done the same way it was proven that *any* $e_L \in e_L^{SBC} \geq e_L^{SOPVC}$ and is left to the reader. Finally, *any* $e_G \in e_G^{FC} \geq e_G^{SBC}$, because $e_G^{SBC} = 0$. ■

2.3. Overinvestment under the SOPVC regime

To highlight that the regime suggested by Miceli and Segerson (2007b), called social optimal property value compensation in Section 3, may indeed induce overinvestment if the government is benevolent, let us consider the following simple example. We consider a non-stochastic situation where there is only one state of the world $\omega \in \Omega$. The value of the landowner's property is given by $V(e_L) = 2\sqrt{e_L}$ whereas the social benefit of the taking is given by $S(e_G) = \frac{4}{3}$. Thus, in the social optimum, optimal investment is given by $e_L^* = e_G^* = 0$ and a taking occurs with certainty. Let us assume that compensation is paid according to the social optimal property value compensation regime proposed by Miceli and Segerson (2007b). Since the socially efficient amount of investment is zero, compensation amounts to $V(0) = 2\sqrt{0} = 0$.

The government, being benevolent, takes the landowner's property whenever $V(e_L) \leq \frac{4}{3}$.[4] The landowner's payoff amounts to:

$$V(e_L) = \begin{cases} -e_L & e_L \leq \frac{4}{9} \\ 2\sqrt{e_L} - e_L & e_L > \frac{4}{9}. \end{cases}$$

Knowing that she receives no compensation if a taking occurs, the landowner invests such that a taking does not occur with certainty. It is thus optimal for the landowner to overinvest, $e_L = 1$. In a stochastic example, the landowner would have an incentive to overinvest to reduce the probability that a taking occurs.

[4]Our overinvestment result holds independent of the tie-breaking assumption.

3. Appendix to Chapter III

3.1. Mixed Strategy Equilibria

In the main part of the chapter we have established our breakdown result for equilibria in pure strategies only. In this section, we demonstrate that if a breakdown is the unique equilibrium outcome in pure strategies it must also be the unique equilibrium outcome in mixed strategies. It is clear that the introduction of mixed strategies does not make it more likely that an agreement equilibrium exists in the sequential case. Recall that the airport ex-ante knows that it makes a loss if it reaches an agreement with one of the farmers. Thus in equilibrium, the airport only makes offers that the farmers reject with certainty.

A more interesting case to consider is whether our breakdown result continues to hold if the farmers can use mixed strategies after a simultaneous offer by the airport. In the main part, we argued that for both farmers to accept a simultaneous offer, the airport has to offer them at least their respective Rubinstein payoffs. This payoff they can ensure themselves by refusing the airport's offer, given that the other farmer accepts. If the farmers use mixed strategies, it may be possible that the airport offers less than the farmers' respective Rubinstein payoffs which they accept with positive probability. Before we establish that even then a breakdown may be the unique equilibrium outcome, let X_1, X_2, X_A denote the parties' payoffs if both farmers reject the offer[5] and p_1, p_2 the probabilities with which the farmers accept the offer.

Let us first consider case (iii) where, if only one of the farmers rejects the offer, the Rubinstein game starts in the same period. Then, the airport's payoff is given by

$$\begin{aligned}\sigma_A = {} & p_1 p_2 (S - B_1 - B_2) + p_1(1 - p_2)(S - B_1 - R_2) \\ & + (1 - p_1)p_2(S - R_1 - B_2) + (1 - p_1)(1 - p_2)X_A. \qquad \text{(A.4)}\end{aligned}$$

We can rule out equilibria in which one farmer, say farmer 1, accepts or

[5] If the game ends after both farmers rejected the offer, $X_A = 0$ and $X_1 = V_1, X_2 = V_2$

rejects with certainty. In that case, farmer 2 must at least receive his Rubinstein payoff to accept the offer with positive probability. Then, the airport's payoff amounts to $S - B_1 - R_2$ independent of whether farmer 2 accepts the offer or not. Because trade cannot occur sequentially and $B_1 \geq V_1$, we know that this term is negative. Thus, the airport is better off to make an offer that both farmers reject with certainty. Let us now consider the case where both farmers accept and reject with positive probability. In any mixed strategy equilibrium, the farmers must be indifferent between acceptance and rejection, which implies:

$$B_1 = p_2(R_1 - X_1) + X_1 \text{ and } B_2 = p_1(R_2 - X_2) + X_2. \tag{A.5}$$

Using (A.5) , we can rewrite (A.4) as

$$\begin{aligned} \sigma_A = & \overbrace{p_1(S - R_2 - X_1)}^{<0} + \overbrace{p_2(S - R_1 - X_2)}^{<0} \\ & \underbrace{-p_1 p_2(S - X_1 - X_2)}_{<0} + (1 - p_1)(1 - p_2)X_A < X_A. \end{aligned} \tag{A.6}$$

Recall that $X_1 \geq V_1$ and $X_2 \geq V_2$. Because trade cannot occur sequentially, $S - R_2 - X_1 < 0$ and $S - R_1 - X_2 < 0$. Thus, the left hand side of (A.6) is strictly smaller than X_A. Because the airport can ensure itself a payoff of X_A by making offers that both farmers reject with certainty, we can conclude that it has no incentive to make offers that the farmers accept with positive probability.

Let us now consider case (iv) where if only one of the farmers accepts the airport's offer, the Rubinstein game between the airport and the other farmer begins one period later. This implies that the price for the first parcel is paid immediately whereas the value of the runway S and the price paid for the second parcel are discounted once. We can write the airport's payoff as

$$\begin{aligned}\sigma_A &= p_1p_2(S - B_1 - B_2) + p_1(1-p_2)[\delta_A S - B_1 - \delta_A R_2 + (1-\delta_A)V_1^A] \\ &\quad + (1-p_1)p_2[\delta_A S - B_2 - \delta_A R_1 + (1-\delta_A)V_2^A] + (1-p_1)(1-p_2)X_A \\ &= p_1p_2[(1-2\delta_A)S + \delta_A R_2 + \delta_A R_1 - (1-\delta_A)V_1^A - (1-\delta_A)V_2^A] \\ &\quad + p_1[\delta_A S - B_1 - \delta_A R_2 + (1-\delta_A)V_1^A] \\ &\quad + p_2[\delta_A S - B_2 - \delta_A R_1 + (1-\delta_A)V_2^A] + (1-p_1)(1-p_2)X_A \qquad \text{(A.7)}\end{aligned}$$

where $(1-\delta_A)V_1^A$ and $(1-\delta_A)V_2^A$ represent that should the airport acquire one parcel only, it can use this parcel for one period. With the same reasoning as in case (iii), we need to consider $(p_1, p_2) \in (0,1)\times(0,1)$ only. That the farmers must be indifferent between acceptance and rejection implies

$$\begin{aligned}B_1 &= p_2(\delta_1 R_1 + (1-\delta_1)V_1) + (1-p_2)X_1 \text{ and} \\ B_2 &= p_1(\delta_2 R_2 + (1-\delta_2)V_2) + (1-p_1)X_2. \qquad \text{(A.8)}\end{aligned}$$

Using (A.8), we can rewrite (A.7) as

$$\begin{aligned}\sigma_A &= (1-p_1)(1-p_2)X_A + p_1p_2[(1-2\delta_A)S + \delta_A R_2 + \delta_A R_1 - (1-\delta_A)V_1^A \\ &\quad - (1-\delta_A)V_2^A - \delta_1 R_1 - (1-\delta_1)V_1 - X_2 - \delta_2 R_2 - (1-\delta_2)V_2 - X_2] \\ &\quad + p_1 \underbrace{[\delta_A S - X_1 - \delta_A R_2 + (1-\delta_A)V_1^A]}_{<0} \\ &\quad + p_2 \underbrace{[\delta_A S - X_2 - \delta_A R_1 + (1-\delta_A)V_1^A]}_{<0}. \qquad \text{(A.9)}\end{aligned}$$

Note that because $X_1 \geq V_1$ and $X_2 \geq V_2$ and because it is not profitable for the airport to acquire the parcels sequentially, the terms in the last line are smaller than zero. Let us multiply these two terms by p_1 and p_2, respectively. Because we leave the first and the second line of (A.9) unchanged, the total expression must be bigger than σ_A. Hence

$$\begin{aligned}
\sigma_A &< (1-p_1)(1-p_2)X_A + p_1p_2[(1-2\delta_A)S + \delta_A R_2 + \delta_A R_1 - (1-\delta_A)V_1^A \\
&\quad - (1-\delta_A)V_2^A - \delta_1 R_1 - (1-\delta_1)V_1 - X_2 - \delta_2 R_2 - (1-\delta_2)V_2 - X_2] \\
&\quad + p_1p_2[\delta_A S - X_1 - \delta_A R_2 + (1-\delta_A)V_1^A] \\
&\quad + p_1p_2[\delta_A S - X_2 - \delta_A R_1 + (1-\delta_A)V_1^A] \\
&\quad = (1-p_1)(1-p_2)X_A \\
&\quad + p_1p_2[S - \delta_1 R_1 - \delta_2 R_2 - X_1 - X_2 - (1-\delta_1)V_1 - (1-\delta_2)V_2] \\
&\quad < p_1p_2[S - \delta_1 R_1 - (1-\delta_1)V_1 - \delta_2 R_2 - (1-\delta_2)V_2] \\
&\quad + (1-p_1)(1-p_2)X_A < X_A.
\end{aligned}$$

Because trade is also not possible simultaneously in pure strategies, the bracketed term in the last line is smaller than zero (see Condition 4). Hence, the airport is better off to make offers that the farmers reject with certainty.

3.2. Proof of Lemma 1

In order to prove Lemma 1, let $\Gamma(k)$ denote the size of the pie the airport and farmer k negotiate over. From the main part, we know that the pie between the airport and the last farmer is given by

$$\Gamma(N) := S - \frac{(N-1)V^A + V}{N}. \tag{A.10}$$

Anticipating the size of the pie the airport and farmer k negotiate over, the airport and farmer $k-1$ negotiate over a pie of size

$$\begin{aligned}
\Gamma(k-1) :&= \overbrace{\delta_A\left(\frac{(1-\delta_F)\Gamma(k)}{1-\delta_A\delta_F} + \frac{(k-1)V^A}{N}\right) + (1-\delta_A)\frac{V^A(k-1)}{N}}^{\text{Joint surplus in case of trade}} - \\
&- \underbrace{\left[\frac{(k-2)V^A}{N} + \frac{V}{N}\right]}_{\text{Joint surplus in case of no trade}} \\
&= \delta_A\left(\frac{(1-\delta_F)\Gamma(k)}{1-\delta_A\delta_F}\right) - \frac{V-V^A}{N}
\end{aligned}$$

Here, $\frac{(1-\delta_F)}{1-\delta_A\delta_F}$ represents the fraction the airport gets from the total bargaining pie. The term $\frac{(k-1)V^A}{N}$ represents the fact that the airport owns $k-1$ parcels if it agrees with farmer $k-1$ and can use these parcels for one more period. As mentioned in the main part, a bargaining pie may in principle be negative. Because this directly implies that the airport and farmer 1 would never have agreed, let us define the function $\Gamma(k)$ as if the parties would also share negative pies according to the Rubinstein formula. Note that $\Gamma(k) \geq \frac{V-V^A}{N}, \forall k = 1, ..., N$ is a necessary condition for trade to occur: If any airport-farmer pair bargains over a pie of strictly negative size, it is optimal for them to stop negotiating. If these inequalities hold strictly, all airport-farmer pairs bargain over a strictly positive pie and thus reach an agreement. Hence, $\Gamma(k) > 0, \forall k = 1, ..., N$, is a sufficient condition for trade to occur. Let us derive $\Gamma(k)$ by induction:

Lemma 2:

$$\Gamma(k) = \left(S - \frac{(N-1)V^A + V}{N}\right)\left(\frac{\delta_A(1-\delta_F)}{1-\delta_A\delta_F}\right)^{N+1-k} - \sum_{i=k+1}^{N} \frac{V-V^A}{N}\left(\frac{\delta_A(1-\delta_F)}{1-\delta_A\delta_F}\right)^{N+1-i}. \tag{A.11}$$

Proof. Let us first show that the statement is true for the induction basis. Plugging in $k = N$ yields the **Induction basis:**

$$\Gamma(N) = S - \frac{(N-1)V^A + V}{N} \tag{A.10}$$

which is the size of the pie the airport and the last farmer negotiate over. We still have to prove that if the statement holds for k it also holds for $k-1$:

Induction step: Given $\Gamma(k)$ as defined in (A.11),

$$\begin{aligned}\Gamma(k-1) &= \frac{\delta_A(1-\delta_F)}{1-\delta_A\delta_F}\Gamma(k) - \frac{V-V^A}{N}\\ &= \left(S - \frac{(N-1)V^A+V}{N}\right)\left(\frac{\delta_A(1-\delta_F)}{1-\delta_A\delta_F}\right)^{N+2-k}\\ &- \sum_{i=k+1}^{N}\frac{V-V^A}{N}\left(\frac{\delta_A(1-\delta_F)}{1-\delta_A\delta_F}\right)^{N+2-i} - \frac{V-V^A}{N}\\ &= \left(S - \frac{(N-1)V^A+V}{N}\right)\left(\frac{\delta_A(1-\delta_F)}{1-\delta_A\delta_F}\right)^{N+1-(k-1)}\\ &- \sum_{i=k}^{N}\frac{V-V^A}{N}\left(\frac{\delta_A(1-\delta_F)}{1-\delta_A\delta_F}\right)^{N+1-i}\\ &= \Gamma(k-1)\end{aligned}$$

which proves the lemma. ■

We know that $\Gamma(k) \geq \frac{V-V^A}{N}, \forall k = 1, ..., N-1$ is a necessary condition for trade to occur. Plugging in $k = 1$ and reorganizing yields (III.6), which proves the first part of Lemma 1.

From the recursive definition, we can deduce that $\Gamma(k)$ is strictly increasing in k. Hence, if $\Gamma(k_0) \leq \frac{V-V^A}{N}$ for some k_0, $\Gamma(k) < 0, \forall k < k_0$ must hold. Hence, if $\Gamma(1) > \frac{V-V^A}{N}$, all bargaining pies $\Gamma(k)$ are strictly larger than $\frac{V-V^A}{N}$. Hence, all airport-farmer pairs negotiate over a pie of strictly positive size, which proves the second part of Lemma 1.

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