Essays on bargaining and organisations

A thesis submitted for the degree
of Doctor of Philosophy of
the Australian National University

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This thesis contains no material which has been accepted for the award of any other degree or diploma in any university. To the best of the author's knowledge and belief, it contains no material previously published or written by another person, except where due reference is made in the text. Chapter 5 of the thesis resulted from joint work with fellow student, Vladimir Smirnov.

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Contents

List of Figures

List of Tables

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Abstract

This thesis makes three important contributions to the existing literature. First, it develops a new explanation for delays in bargaining. In the theoretical model presented, two parties are in an on-going relationship. Further, reaching agreement weakens the claim on surplus for one of the parties in subsequent bargaining periods. As a result, this player will require compensation for these future losses if they are to agree. If adequate compensation is not forthcoming, perhaps because of wealth constraints, that player will delay reaching agreement even if it reduces total surplus. Second, the predictions of this new theoretical model are compared to the empirical evidence of innovation and the delay of innovation in Australian workplaces. This empirical analysis examines: the probability of innovation; the attitudes of employees and unions to these changes; and the characteristics of workplaces that were prevented from innovating (workplaces that delayed). This is the first study to examine labour's attitude towards innovation. It is also the first study that contains a direct measure of delay. The empirical estimations show support for some of the key predictions of the model. Third, the thesis develops a hold-up model in which the parties can make specific investments simultaneously or sequentially. Contracting is only possible after at least one investment is sunk. With simultaneous investment, renegotiation occurs after both investments have been made. With sequential investments, after the leader has sunk their investment contracting is possible; as a consequence the follower does not get held-up. This is an advantage of the sequential regime. However, sequential investment disadvantages the lead investor, decreasing their incentive to invest. Consequently, the timing of invest-

ment can act as an additional form of hold-up. This is a new result: the timing of investment can act to reduce total surplus and, in the extreme, prevent trade from occurring.

CHAPTER 1

Introduction

Economic activity often occurs when contracts are incomplete. For example, it may be difficult to succinctly specify the detail of each party's obligations so that they are verifiable by a third party, even if there is consensus between the trading parties at the time. Given this contracting environment, parties will invest and trade with the knowledge that renegotiation could occur. This thesis investigates the impact of incomplete contracts on bargaining and investment.

Bargaining is fundamental in economics. Reaching agreement not only determines the distribution of rents it can also increase total welfare by facilitating trade. On the other hand, disagreement or protracted negotiations reduce the total surplus available. Costly delays arise when a party's concern over the distribution of rents dominates their personal losses from the reduction in total surplus.

Chapter 3 develops a new model that explains delays in bargaining (or innovation) when: there are multiple bargaining periods; previous outcomes affect the subsequent distribution of surplus; contracts are incomplete; and the parties are wealth constrained. In this new model the two parties can choose to adopt a new innovation in each period of the game. (The basic model has two periods.) The innovation generates a known surplus that can be shared between the parties. Innovation, however, affects each party's claim on rents in future periods. When immediate innovation adversely affects a player's future payoff, that player will only be enticed to accept innovation if the immediate returns are sufficiently great so as to compensate her for these future losses. If this is not the case, the player will choose to delay, even if this decision reduces total surplus.

A crucial element in the story of delay is that the parties are unable to write a fully contingent contract. The incompleteness in the model arises because the relevant innovation at any point in time is unverifiable until the commencement of that period.[†] Further, it is assumed that the surplus generated is always unverifiable preventing the parties from writing a surplus sharing agreement.

As a concrete example, consider a union bargaining with a firm that wishes to introduce a change in workpractices that would increase total surplus. The change could be the removal of some restrictive workpractice that provides union members with utility.[†] By assumption, change would increase overall welfare. As a result, the gain in surplus to the union of the current practice does not outweigh the cost to the firm in terms of forgone surplus.

However, the innovation also has the effect of reducing the union's claim on surplus (bargaining power) in the future. For instance, agreeing to allow non-union labour in a closed shop reduces the union's bargaining position in the future. Alternatively, the adoption of a new technology may reduce the firm's reliance on a group of workers with a particular skill, reducing their potential claim on surplus in future bargaining periods. Given this, the union would need to be compensated for both current and future losses. If this cannot be achieved through an adequate compensation package, or a credible promise of future payments, a union may decline to innovate, even if the change is efficient as it would increase overall surplus.

Current agreements affect parties' claim on future surplus either by altering their default payoffs (historical bargaining/contractual positions) or by changing their relative contemporaneous bargaining strengths. Delay will occur at different times depending on which assumption applies. If agreement reduces the future default payoffs of a party, delay is more likely when expected future surplus is lower. If innovation reduces current bargaining power, however, a party is more

[†]Contractual incompleteness can also arise when the parties are unable to commit not to renegotiate.

[†]For instance, some rules provide workers with on-the-job leisure. The workplace could be a closed shop allowing the union to extract rents. Alternatively, the current workplace agreement may prevent the adoption of a new technology that would involve a loss of jobs or require employees to work harder.

likely to delay agreement when expected future surplus is larger. It is also argued in Chapter 3 that a party with a narrowly defined set of interests, like a craft union, is more likely to delay than a party with broader interests, reaffirming the results of Dowrick and Spencer (1994).

The new model of bargaining delays presented in this thesis is compared with the existing literature, reviewed in Chapter 2. As noted above, delays in bargaining typically arise in non-cooperative bargaining models when there is some asymmetric information between the parties. With asymmetric information, delays in bargaining may occur because the informed party uses delay to signal their bargaining strength. These delays, however, may not be lengthy as, once the bargaining strength of a party has been revealed, it is in the interests of both parties to reach agreement.† On the contrary, lengthy delays arise in the incomplete contracts model presented in this thesis.

In addition, recent literature that shows that delays in bargaining can occur with complete information.† These models typically exhibit multiple equilibria, some of which involve delay when the parties play complicated history-dependent strategies. In contrast, the model presented in this thesis has a unique subgame perfect equilibrium. Further, delay arises naturally when the bargaining parties play simple and realistic strategies.

Failure to adopt a change that increases total surplus is a form of a delay (Kennan and Wilson 1993, p. 45-46). With this point in mind, the model is applied to several case studies of delays, including: the adoption of new computer printing technology by newspaper proprietors in the United Kingdom; stalling of process reform in the automotive industry in the United Kingdom; union resistance to change on the wharves in Australia, United States of America and the United Kingdom; and opposition to social policy reform in Australia. These examples emphasise how reform often reduces the bargaining power of one of the parties in an on-going

†Further, if it is difficult to screen different bargaining parties from one another, delay may be an ineffectual screening device.

†See, for example, Haller and Holden (1990), Fernandez and Glazer (1991), Avery and Zemsky (1994a) and Busch and Wen (1995).

relationship. Moreover, opposition to innovation arises when promises concerning future actions or payments are not credible.

Using the Australian Workplace Industrial Relations Survey 1995, Chapter 4 examines innovation in Australian workplaces. This empirical evidence is then compared with the predictions of the new theory of delays in bargaining. Three models are estimated, each exploring a different aspect of innovation and delay. The first model examines the probability of innovation. The second looks at the attitudes of unions and workers to a workplace innovation. The third model compares the characteristics of firms that were prevented from introducing innovation with those that did not experience delay. This is the first time attitudes towards innovation and a variable directly measuring delay have been used in such a study. Overall, the empirical evidence is consistent with the predictions of the theory, in particular the predictions concerning future surplus and the incentive to delay.

Chapter 5 explores the hold-up problem when trading parties can choose to make specific investments simultaneously or sequentially. An advantage of staging investments is that contracting on any subsequent investment becomes possible after the project is under way and better defined. It is shown in the model that there can be efficiency improvements with the sequential regime, as compared with simultaneous investment, if the parties are sufficiently patient. Further, as previously emphasised in the literature, sequencing of investments can allow some projects to proceed that would not be feasible with a simultaneous regime.[†] This is not always the case, however. A cost of sequencing investment is that it can disadvantage the party that makes the initial investment, reducing their incentive to invest. In fact, the mere possibility of sequential investment can be detrimental to overall welfare. In the extreme it can prevent mutually beneficial trade from occurring. This is a new result: it allows the choice about the timing of investment to be interpreted as a new (potential) form of hold-up.

Further, the decision over the timing of investment can be seen as a choice over the completeness of contracts: if parties opt for simultaneous investment they are

[†]See, for example, Neher (1999) and Admati and Perry (1991).

opting for a more incomplete contract than necessary. As a result, the choice concerning the completeness of contract is endogenous. The advantage of a (more) complete contract with sequential investment is that hold-up of the follower is avoided. The cost of a complete contract is that it diminishes the first party's incentive to invest. A party will opt for simultaneous investment - that is, they will opt for an incomplete contract - when their gain from the increase in total surplus outweighs the additional bargaining power they receive from avoiding hold-up.

Finally, interesting dynamics can arise out of this investment game when both parties want to be a follower rather than the leader. If there are just two potential investment periods (and the opportunity to invest disappears after the second period) the parties find themselves in a prisoners' dilemma. If the potential investment horizon is continually extended to three periods, four periods and so on, eventually the benefit from not investing (waiting) will diminish sufficiently so that the players will find themselves in a coordination game. (The players will mix between investing immediately and waiting.) If the horizon is extended further from this point, with certain parameter values it is possible that the players will again return to a prisoners' dilemma game. This arises because the payoff in the coordination game (say in period K) alters the expected return from waiting in the game with the longer horizon (say a game of $K + 1$ periods). It is possible that the optimal strategies switch between a prisoners' dilemma game and a coordination game as the potential horizon is extended. As far as I am aware, there are no games in the existing literature that exhibit this sort of dynamic switching.

CHAPTER 2

Non-cooperative models of bargaining: a literature review

2.1 Introduction

This chapter provides a selective review of non-cooperative bargaining models. In particular, it examines the conditions necessary for bargaining parties to delay reaching agreement. Delay may take several different forms (Kennan and Wilson 1993, pp. 45-46). Two parties may engage in protracted negotiations or fail to reach any agreement. Alternatively, they could reach an inefficient agreement in that not all of the potential gains from trade are realised. If there are costs of delay (for example because the parties discount the future) any delay in reaching a settlement reduces the total surplus available. On the other hand, if the parties bring agreement forward it is possible to make at least one party better off without making the other party worse off. That is, if the parties take the agreement reached after the delay as providing default payoffs to each party, there is an opportunity to make a second bargain over the additional surplus generated if agreement is reached earlier. Reaching agreement over this second bargain is in the interest of all parties concerned as they can only benefit. This is the basic logic of the equilibrium in the alternating-offer models with complete information, notably Rubinstein's (1982) model, reviewed in section 2.2. This model forms the basis of much of the existing non-cooperative bargaining literature.

Section 2.3 examines how bargaining delays may arise when there is asymmetric information between the parties. As well as alternating-offer models, this section also discusses one-sided offer models. These models are used to simplify the signaling process in the presence of asymmetric information.

Recently, other authors have developed bargaining models with symmetric information in which delay can occur. Their models are discussed in section 2.4. Section 2.5 links the results examined here with the other models developed in this thesis.

The main implications of the non-cooperative models presented are:

- With complete information, agreement between the bargaining parties is typically reached immediately, thereby maximising total available surplus.
- Outside options only affect the bargaining outcome when they can be credibly employed.
- The inability to commit to an offer affects the outcome of bargaining models. In models with asymmetric information the seller is made worse off (ex ante) by their inability to commit to a particular price.
- With asymmetric information, delays in bargaining may occur because the informed party uses delay to signal their bargaining strength. However, these delays may not be lengthy.
- Delays may arise with symmetric information when the parties are uncertain about the future value of the surplus and when they are unable to write a contingent contract.
- Party specific externalities may give rise to bargaining delays.
- Inefficient equilibria (delays) can be sustained with complete information if there are multiple equilibria and if deviations can be credibly punished.

The arguments discussed in this chapter draw heavily on other surveys of non-cooperative bargaining, particularly Sutton (1986), Osborne and Rubinstein (1990) and Kennan and Wilson (1993).

2.2 Alternating-offer models with complete information

In alternating-offer bargaining models, the parties take turns to propose and respond to offers relating to the division of surplus produced by the completion of a given transaction. Offers may explicitly involve proposals relating to how the surplus is to be divided or they may involve the parties agreeing on a transaction price: the transaction price determines the partition of surplus in this case.

This section first examines an alternating-offer model with a finite horizon. This model is then extended to an infinite horizon, as expounded by Rubinstein (1982). Several extensions are discussed, including the effect of allowing the parties to have outside options and how the inability of the proposer to commit to an offer affects the equilibrium outcome of these bargaining models.

2.2.1 Alternating-offer bargaining with a finite horizon

Following Stahl's (1972) alternating-offers bargaining game with a finite horizon, two players must agree on how to divide a 'cake' or surplus the size of which has been normalised to equal 1. Feasibility requires that $x_1 + x_2 \leq 1$, where x_i is the share of player i and $i = \{1, 2\}$.[†]

Figure 2.1 illustrates the bargaining process. In period $t = 0$ player 1 makes a proposal on the division of the cake to player 2, $(x_1, 1 - x_1)$. Player 2 may accept or reject this proposal. If player 2 accepts the offer the game ends and each player receives the share proposed. If player 2 rejects the offer the game proceeds to the second period. In the period $t = 1$, player 2 makes an offer to player 1 concerning the division of the cake, namely $(x_1, 1 - x_1)$. If player 1 accepts this offer, each party receives the payments prescribed by player 2's offer and the game ends. If player 1 rejects the offer, the game proceeds to period $t = 2$, in which each player receives a payment (y_1, y_2). This payment is exogenously predetermined and it is assumed that $y_1 + y_2 \leq 1$. Each player knows the structure of the game and there is no uncertainty.

[†]It is assumed that the cake is infinitely divisible, so x_i may take any value between 0 and 1.

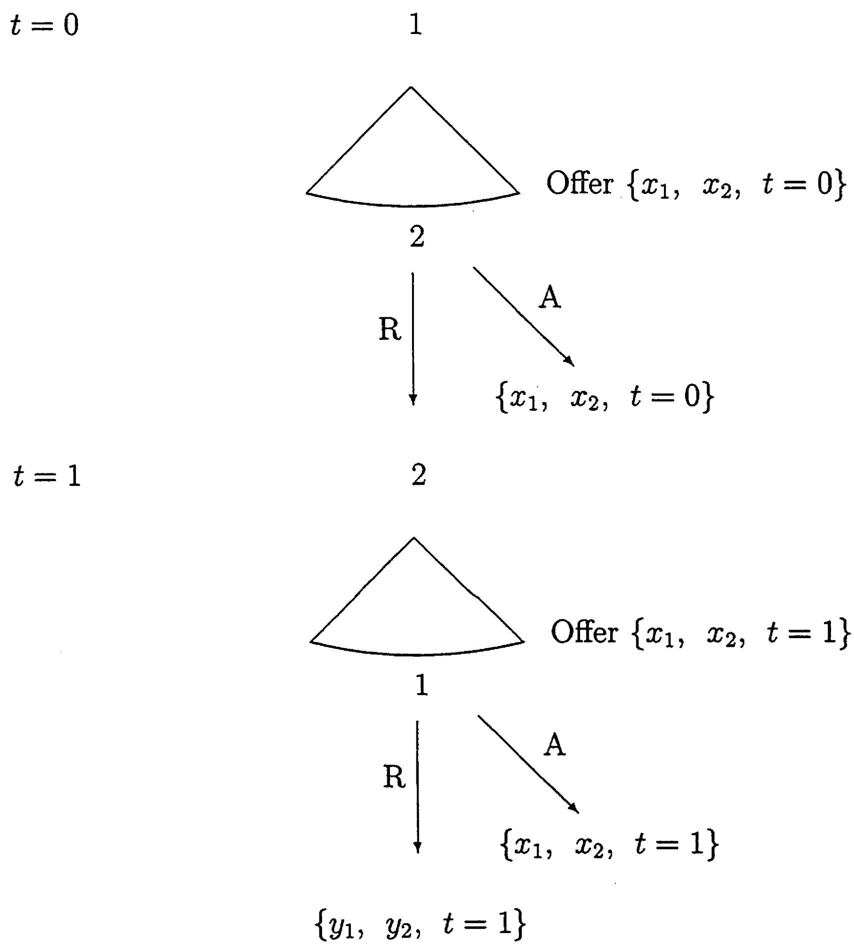

Figure 2.1: Finite horizon alternating bargaining model

The payoff (utility) for player i is $\delta_i^t x_i$, where δ_i is a discount factor for player i, and t is the period in which the payment is made, for example the utility of player 1 would be x_1 if agreement were made in period $t = 0$, $\delta_1 x_1$ if the payment was made in period $t = 1$. If the parties do not reach agreement in the first two periods the payoffs to player 1 and 2 are $(\delta_1^2 y_1, \delta_2^2 y_2)$.

This bargaining game can be solved by backwards induction. In period $t = 1$ player 2 makes an offer to player 1. As player 1 knows he will receive y_1 if bargaining extends to the next period, he will reject any offer by player 2 in which he receives less than $\delta_1 y_1$. That is, for there to be agreement in period $t = 1$ player 1 must be at least as well off as if he refused the current offer (delayed agreement) and continued the bargaining process to the next period. Given this, player 2 will offer the division $(\delta_1 y_1, 1 - \delta_1 y_1)$ at time $t = 1$ so as to make player 1 indifferent between accepting and rejecting the offer. As player 1 discounts the future with a discount factor of δ_1, in period $t = 1$ player 1 will accept any offer $x_1 \geq \delta_1 y_1$.

In period $t = 0$, anticipating the outcome in the subsequent subgames, player 2 will not accept any proposal by player 1 that gives her a payoff less than $\delta_2(1 - \delta_1 y_1)$, which is her payoff from delaying agreement in period $t = 1$ and making an offer that is accepted by player 1 in the next period, appropriately discounted. Knowing this, player 1 makes the proposal $(1 - \delta_2(1 - \delta_1 y_1), \delta_2(1 - \delta_1 y_1))$ in period $t = 0$, and player 2 accepts this offer. This subgame perfect equilibrium outcome is unique. As there is not delay joint surplus is maximised.

Further to this, player i's payoff is increasing with their patience (δ_i increases), is decreasing as the other player becomes more patient and is increasing in their default (non-agreement) payoffs. These characteristics are summari~~es~~sed in Result 2.1.

Result 2.1 *In the finite horizon alternating-offer game the subgame perfect equilibrium is unique and agreement is reached immediately, maximising joint surplus. Each player's share of the surplus is increasing in their own patience, decreasing in the patience of the other player and increasing in their default (non-agreement) payoff.*

2.2.2 Alternating-offer bargaining model with an infinite horizon

In 1982 Rubinstein developed the alternating-offer bargaining model with an infinite horizon shown in Figure 2.2. In period $t = 0$, player 1 gets to make an offer of how the cake of size 1 is to be divided between herself and player 2. As in the finite horizon model above, player 2 can accept or reject this offer. If player 2 agrees with the proposal, the payments specified in the proposal are made and the game ends. If player 2 rejects the proposal the game proceeds to period $t = 1$ in which player 2 gets to make an offer. As in the first round of bargaining, if player 1 accepts the offer the agreed payments are made and the game ends. If player 1 rejects the offer the game continues to period $t = 2$. In this period player 1 again gets to make an offer to which player 2 responds. If an agreement is not reached this process of alternating offers continues indefinitely.

The utility of each player is $\delta_i^t x_i$, where $\delta_i \in (0, 1)$ is the discount factor of player i and t is the period in which agreement is reached.

Any division of the surplus can be sustained as a Nash equilibrium. Consider the following strategy of player 1: offer the division $(\overline{x}_1, 1 - \overline{x}_1)$ in every period in which she gets to make an offer; only accept an offer from player 2 if $x_1 \geq \overline{x}_1$. Player 2 plays an analogous strategy: propose $(\overline{x}_1, 1 - \overline{x}_1)$; accept an offer if and only if $x_1 \leq \overline{x}_1$. Given the strategy of each player, neither player can do better by unilaterally deviating from their strategy. As such, the Nash equilibrium places few restrictions on the outcome of this game.†

However, the bargaining game has a unique subgame perfect equilibrium (SPE) that may be solved for using the stationarity of the game, outlined Shaked and Sutton (1984).† To find the SPE we first establish the maximum payoff for player 1 in any SPE. Second, we demonstrate that this is the unique SPE outcome as it is also equal to the minimum payoff that player 1 would receive in any SPE.

First, let $\overline{M}$ be the largest payoff player 1 can obtain in any SPE. Thus at

†See Osborne and Rubinstein (1990, pp. 41-43).

†For a discussion of this technique also see Sutton (1986), Osborne and Rubinstein (1990, section 3.8), Mas-colell et al (1995, pp. 298-99) and Gibbons (1992, pp. 70-71).

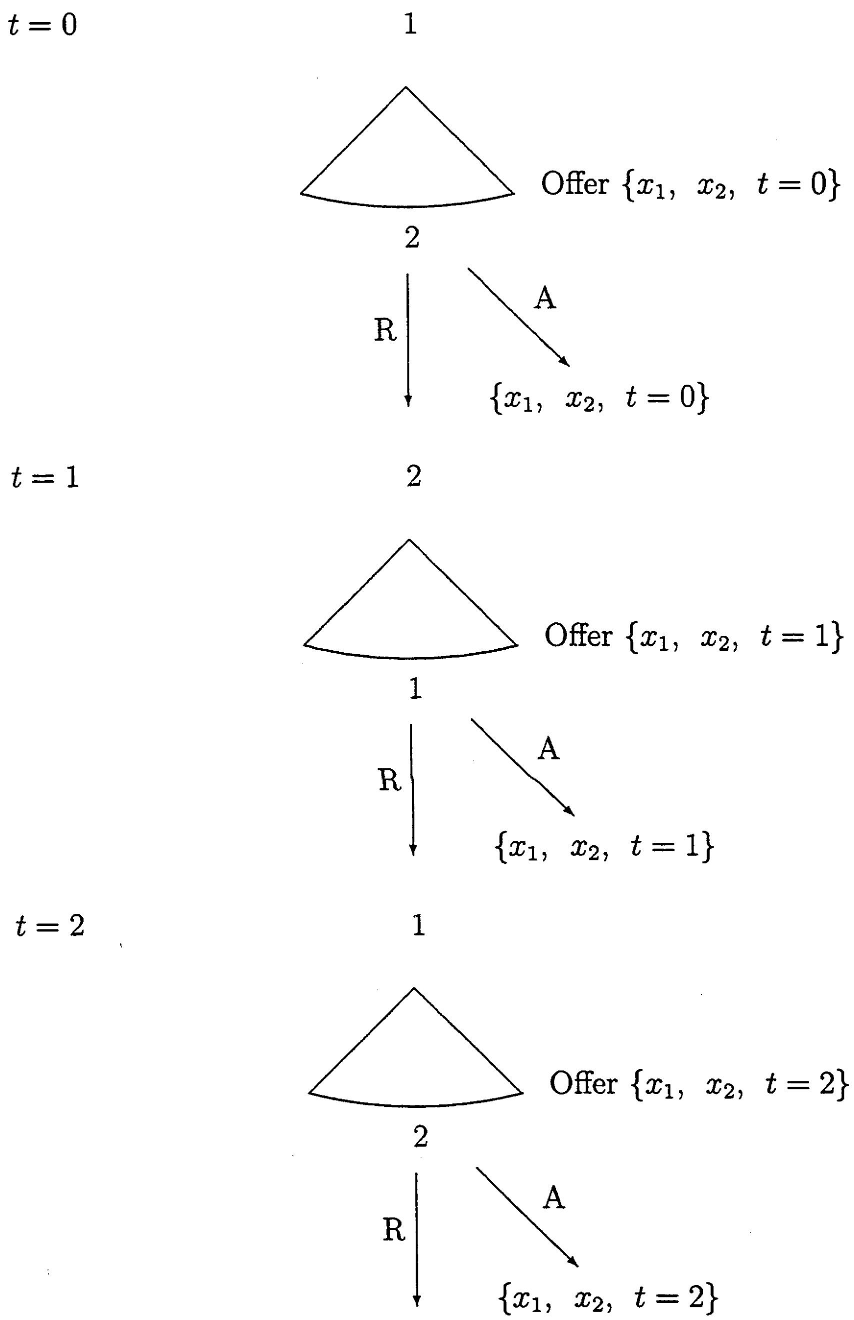

Figure 2.2: Rubinstein's (1982) alternating offers bargaining game

time t = 2 the maximum player 1 can expect is $\overline{M}$. Given this, at time t = 1, player 2 can do no better than to offer player $1 - \delta_1\overline{M}$. If player 2 offers less than $1 - \delta_1\overline{M}$ in period $t = 1$, player 1 will reject the offer and wait for the next period. Repeating this procedure, at time $t = 0$, player 1 must offer at least $(1-\delta_2(1-\delta_1\overline{M}))$ to player 2 to get his agreement. However, given the stationarity of the game at time t = 0, payoff for player 1 is the same as the payoff at time t = 2. That is, $(1 - \delta_2(1 - \delta_1\overline{M})) = \overline{M}$, or $\overline{M} = (1 - \delta_2)/(1 - \delta_1\delta_2)$.

Second, to show this is a unique outcome, let $\underline{M}$ be the smallest payoff that player 1 will receive in a SPE. Repeating the backwards induction arguments above, $\underline{M}$ = $(1 - \delta_2)/(1 - \delta_1\delta_2)$ must be the smallest payoff for player 1 in a SPE. As $\underline{M}$ = $\overline{M}$ the SPE is unique. Player 1 receives $(1 - \delta_2)/(1 - \delta_1\delta_2)$ and player 2 receives $\delta_2(1 - \delta_1)/(1 - \delta_1\delta_2)$. If $\delta_1 = \delta_2$, player 1 receives $1/(1 + \delta)$ and player 2 receives $\delta/(1 + \delta)$. The strategies that sustain this SPE are: in every period in which a player makes an offer he proposes a division that corresponds to the SPE outcome in each period; and in every period in which a player responds to an offer that he ~~they~~ only accept an offer if he will ~~they~~ receive a payoff at least as large as he ~~they~~ would receive from delaying agreement.

In a similar manner as in the finite horizon game, agreement is reached in the first period without delay despite the possible infinite horizon of the bargaining process. As each party knows the costs of the delay for themselves and the other player there is no strategic advantage in delaying agreement. Delay only serves to reduce total joint surplus. Thus, reaching agreement earlier increases the total available surplus available. This allows at least one of the players to be better off without making the other player worse off. The only SPE outcome of the game thus involves the parties reaching immediate agreement, maximising joint surplus. The main points of the outcome of this bargaining game are summarised in Result 2.2.

Result 2.2 *In the infinite horizon alternating-offer model, the SPE is unique, agreement is reached immediately and joint surplus is maximised. Each player's payoff is increasing in their own patience and is decreasing in the discount factor of the other player.*

Note also that there is an advantage in being the first mover in this game. Several authors modified the model to remove this first mover advantage. Sutton (1986, p. 711) argued that as the time difference between bargaining periods Δ tends to zero the share of player 1 becomes $\frac{ln\delta_2}{(ln\delta_1+ln\delta_2)}$. When $\delta_1 = \delta_2$, this equals 1/2. Alternatively, some authors have suggested that at the beginning of each bargaining period the proposer be chosen at random (for example, by the toss of a coin). MacLeod and Malcomson (1993a) used this technique in their bargaining game in which two parties bargain over a flow of surplus, rather than a stock of surplus. As the number of bargaining rounds increases each party becomes the first mover approximately 50 per cent of the time.

Another possible augmentation to the model is to alter the way the players incur delay costs. For example, consider an infinite-horizon alternating-offer game in which each player has a constant cost of delay for every period in which there is delay. That is, the utility function of each player is $u_i = x_i - c_i t$, where $c_i > 0$. If $c_1 \neq c_2$ there is a unique SPE. When $c_1 < c_2$, in the SPE agreement is reached immediately and the division is $(x_1 = 1, x_2 = 0)$. Alternatively, if $c_1 > c_2$ agreement is reached immediately and the partition of the surplus is $(x_1 = c_2, x_2 = 1 - c_2)$. In this game having a lower cost provides the party making the offer with an absolute advantage. Thus if player 1 has a lower cost he receives all of the surplus. On the other hand, if player 2 has a lower cost of delay party 1 must provide her with at least an equivalent payoff as when she delays and gets to make the offer at $t = 1$. If $c_1 = c_2$ there is no longer a unique solution (provided c_i is not too large) and some of the equilibria involve delay, although this delay is never more than one period (see Rubinstein 1982, pp. 107-108, Osborne and Rubinstein 1990, p. 49).

2.2.3 Outside options

Often bargaining parties have the option to quit negotiating and take up an outside option. Figure 2.3 illustrates the extensive form of a model based on Shaked and Sutton (1984). As before, both players must agree on how to share surplus normalised to size 1. In period $t = 0$ player 1 makes an offer to player 2. Player

2 can accept the offer, ending the game, or she can choose to reject the proposal. If player 2 rejects the offer she then has two options: proceed to the next period in which she makes an offer to player 1 as in the standard alternating-offer game described above; or, alternatively, opt to quit the bargaining process and take up an outside option. The game proceeds to the next round provided: the parties do not reach agreement; and player 2 does not exercise her quit option. Again, the potential bargaining horizon is infinite.

The utility of each player is given by $(\delta^t x_1, \delta^t x_2)$, where x_i is the payoff received by player i, $i = \{1, 2\}$. If the quit option is exercised by player 2, player 1 receives a payoff of zero and player 2 gets $b \in (0, 1)$. If the outside option is not exercised, the division of surplus is $(x_1, x_2 = 1 - x_1)$ as agreed. Note that as $b < 1$ the potential surplus is larger inside the relationship than outside it.

First, consider the case when $b < \frac{\delta}{(1+\delta)}$. As $\frac{\delta}{(1+\delta)}$ is the payoff player 2 receives in the SPE when no outside option is available, the existence of the outside option does not affect the division of surplus. Following the technique described in section 2.2.2, player 1 will propose $(1/(1+\delta), \delta/(1+\delta))$ in period 1, and accept any offer of $x_1 \geq \delta/(1+\delta)$. The best player 2 can do, given the strategy of player 1, is to accept any offer of $x_2 \geq \delta/(1+\delta)$ and propose the partition $(\delta/(1+\delta), 1/(1+\delta))$. Given these strategies, it is never optimal for player 2 to exercise her outside option and quit. As a result, player 1 will not adjust any of his offers on account of the outside option; the SPE is unaffected by the presence of the outside option.

Second, considering when $b > \frac{\delta}{(1+\delta)}$, the outside option does affect the SPE strategies and outcome of the game. In the unique SPE for this game: player 1 proposes the division $(1 - b, b)$ and accepts an offer if and only if $x_1 \geq \delta(1 - b)$; player 2 proposes $(\delta(1-b), 1-\delta(1-b))$, accepts any offer provided $x_2 \geq b$ and opts out if $x_2 < b$. For example, consider an offer of $x_2 < b$ in period $t = 0$. If player 2 rejects the offer and continues bargaining, the best he can obtain in period $t = 1$ is $x_2 = 1-\delta(1-b)$, as derived from the equilibrium strategies. Given the stationarity of player 1's strategy she will again offer x_2 in period $t = 2$, at which point player 2 can do no better than opt out. Discounting these payoffs to their respective period

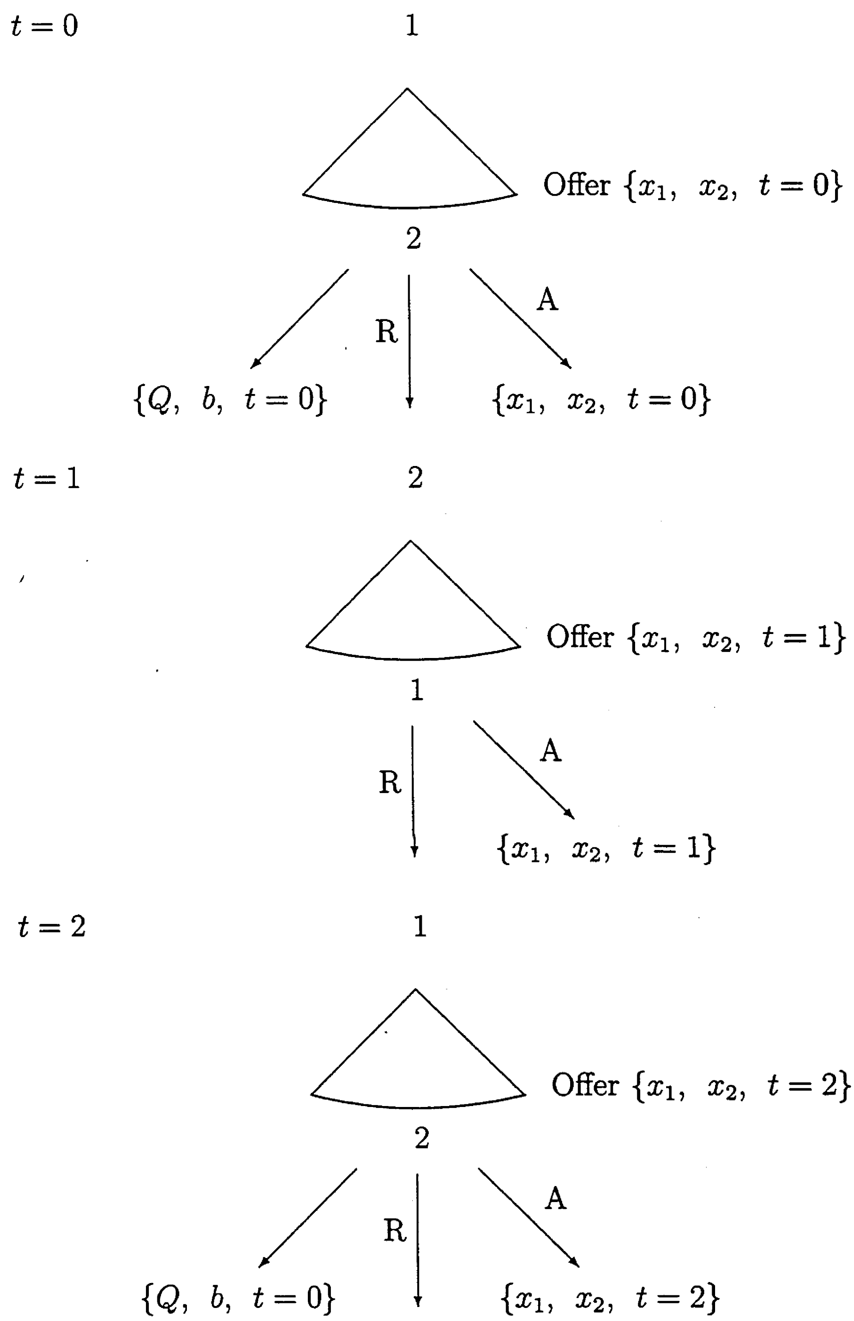

Figure 2.3: Alternating bargaining model with an outside option

$t = 0$ values it is apparent that $\delta^2 b \leq \delta(1 - \delta(1 - b)) < b$. The first inequality holds provided $(1 - \delta) \geq 0$. The second inequality holds by the assumption that $b > \frac{\delta}{(1+\delta)}$. Given that $b > \delta^2 b$, it is optimal for player 2 to immediately quit if $x_2 < b$.

As it is not in the interests of player 1 to have player 2 quit, she will offer at least b in period $t = 0$. Moreover, as player 2 will accept any offer $x_2 \geq b$, player 1 need not offer any more than $x_2 = b$. In the SPE the division of the surplus is $(1 - b, b)$ and agreement is reached immediately.

Third, if $b = \frac{\delta}{(1+\delta)}$, there is immediate agreement and the surplus is divided by the partition $(1 - b, b)$.

Result 2.3 summarises the main aspects of the model.

Result 2.3 *In an alternating-offer model, the SPE is only affected by an outside option if it can be credibly invoked. In the SPE, agreement is reached immediately, maximising potential surplus.*

There are several possible extensions to this model. First, the equilibria of the game are sensitive to the timing of the quit option. If, for example, the structure of the game is altered so that player 2 may only quit after player 1 has rejected one of his offers there are multiple equilibria for some parameter values (see Osborne and Rubinstein 1990, pp. 58-63).

Second, as demonstrated by Shaked and Sutton (1984), the player with the outside option may have to wait T periods before the quit option becomes available.[†] When T is small, the outside option has the effect of giving player 1 (approximately) all the bargaining power so that the model mimics the result of a competitive market (for player 2). Alternatively, if T is large the game approximates a bilateral monopoly, as in Rubinstein's original game.

Third, the game may be altered so that after any rejection the game may be terminated with an exogenously determined probability p as shown in Figure 2.4 (see Sutton 1986, p. 715). In this game, all outside option values affect the equilibrium

[†]Shaked and Sutton assumed that at this point player 1 can begin bargaining with an outside party who is identical to player 2.

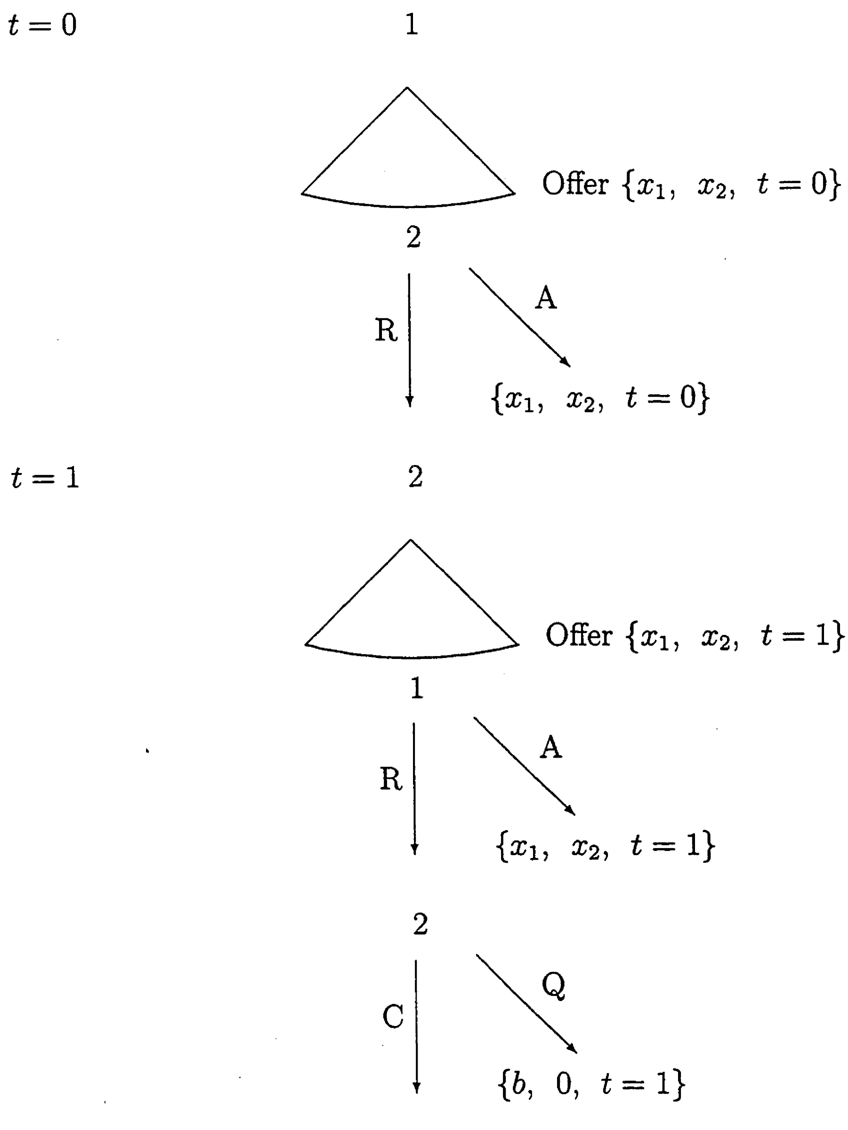

Figure 2.4: Alternative timing for exercising the outside option

payoffs because any rejection could invoke the outside option. As it is exogenously determined whether the bargaining process will end (given an offer has been rejected) these outside options become a credible threat and will affect the bargaining outcome. Moreover, the finite horizon model (section 2.2.1) can be interpreted as a special case of this model where the rejection of an offer by player 1 means that the outside options are invoked with probability $p = 1$.

2.2.4 Commitment

Muthoo (1990) modified Rubinstein's (1982) alternating-offer bargaining game to allow the proposer to be able to withdraw his offer once it had been accepted by the other party. That is, the proposer could reject an acceptance of his initial offer and opt to continue bargaining.

The model was set up as follows. The initial proposer (the seller) values the good at 0 and the other party (the buyer) values the good at 1. Given the alternating structure of the game, the seller makes offers in periods $t = 0, 2, 4, ...$ and the buyer makes all the offers in odd periods. Each party has a discount factor of $\delta \in (0, 1)$, so that the payoffs for the seller and buyer are $p\delta^t$ and $(1-p)\delta^t$ respectively, where p is the agreed upon price.

Although Rubinstein's unique result (that is, $p = \frac{1}{1+\delta}$) can be sustained in equilibrium for any discount factor, Muthoo found that for $\delta \in (\frac{1}{\sqrt{2}}, 1)$ any price between 0 and 1 can be sustained in equilibrium. The reason for the multiplicity of equilibria is similar to the intuition behind the Folk Theorem in repeated games; an equilibrium is sustained through credible threats to punish deviations (and punishing deviations from punishment and so forth). If the discount rate is high enough, any price can be the equilibrium price as it pays neither the proposer or the respondent to deviate from this price. If the proposer deviates, the respondent will punish her by rejecting the offer and making the appropriate punishment offer in the next period. If the respondent accepts an offer she should have rejected, the proposer punishes her by withdrawing the offer and plays a punishment strategy in subsequent bargaining rounds. In equilibrium, the price p is immediately implemented and there is no delay (and the proposer does not change his mind). The possibility that the proposer may withdraw their offer can have a dramatic effect on the outcome of the game.

2.3 Bargaining with asymmetric information

In general, the models of bargaining with complete information reviewed (section 2.2) predict that agreement occurs immediately. These stark results do not always accord with bargaining behaviour observed in practice. One way of explaining delays is to introduce asymmetric information. With private information a costly delay might be the only credible way for a party to communicate the strength of their bargaining position (Kennan and Wilson 1993, p. 46). For example, an agent in a strong bargaining position can signal her strength by making offers that a weaker bargainer would not wish to make. Alternatively, a player may use delay as a screening device to separate players with a high cost of delay from those with a greater willingness/ability to wait. Invariably, these models involve the stronger bargaining agent delaying for a period of time which a weaker agent would not find profitable.

When the parties have incomplete information they must form beliefs about the probability of particular events occurring. As subgame perfection is no longer a useful equilibrium concept we look for a perfect Bayesian equilibrium (PBE) or a sequential equilibrium.[†] Loosely speaking, a PBE requires players to maximise utility given their beliefs, and that these beliefs be formed using Bayes' rule where possible.

In this section we first review bargaining models with one-sided information. Bargaining models with one sided information simplify the signalling process. Next we review a version of Rubinstein's (1982) alternating offer model with incomplete information. The models reviewed in this section show that asymmetric informa-

[†]For further discussion of PBE and sequential equilibrium see Mas-Colell et al (1995, pp. 288-290) or Gibbons (1992, p. 188).

tion can result in costly delays. Furthermore, with a finite horizon asymmetric information can result in the possibility of no agreement at all.

Several authors have questioned the effectiveness of models with one-sided asymmetric information to explain protracted delays.† The argument is that if there are not significant intervals between bargaining periods, and parties cannot commit to future strategies, once a party with a high cost of delay has settled, agreement will reached immediately in the continuation game, given it is now a game with complete information. Realising this, however, the bargainer with a high cost of delay will also delay agreement. As a consequence the separating mechanism breaks down and all parties settle with little or no delay (Hart 1989, p. 26). Section 2.3.3 discusses these arguments and several models that attempt to overcome this criticism. Section 2.3.4 briefly discusses bargaining models with two-sided asymmetric information.

2.3.1 One-sided offer models with one-sided asymmetric information

Consider a one-sided offer bargaining based on the model developed by Fudenberg and Tirole (1983), hereafter FT. A seller makes an offer (or offers depending on the number of bargaining rounds) to a potential buyer who values the good at $b \in \{\underline{b}, \overline{b}\}$. The buyer's valuation is private information but each type occurs with probability $\frac{1}{2}$. The seller's value of the good is 0, and this is known by both parties.

First consider the one period game where the seller makes an offer to the buyer. If the buyer accepts the offer made trade takes place at that price; if the offer is not accepted, no trade takes place and the game ends with each player receiving their default (no trade) payoffs. The default payoffs are equal to zero for both parties, thus it is always efficient to trade. The trade payoffs are $u_s = p$ for the seller and $u_b = b - p$ for the seller.

In the one period game the buyer will accept any offer with a probability of one provided $p \leq b_i$. Given the buyer can only have two possible valuations, the seller will either offer $p = \underline{b}$ and sell to all potential buyers, or she will offer $p = \overline{b}$ and

†See, for example, Gul and Sonnenschein (1988) and Gul, Sonnenschein and Wilson (1986).

sell to the high valuation buyers. Consequently, if $\underline{b} > \overline{b}/2$ then the seller will offer $p = \underline{b}$. Conversely, if $\underline{b} < \overline{b}/2$ the seller will offer $p = \overline{b}$. FT label the first type of seller 'soft' and the second type 'tough'.

Already in the one period game, as a result of a party having private information a surplus enhancing trade may not occur at all. In the case above, this is when $b = \underline{b}$ and the seller offers $p = \overline{b}$ as $\underline{b} < \overline{b}/2$. Note, this would not happen with full information. In that case the seller would always offer a price equal to the buyer's valuation and trade would always occur, maximising surplus.

Now consider the two period game in which the seller can make, at most, two separate offers to the buyer. If the offer in the first period is accepted, the game ends. If, instead, the buyer rejects the first period offer, the seller may make an offer in the second period. If the buyer accepts an offer trade takes place in that period at the specified price. If the buyer rejects the second period offer the game ends and no trade takes place. The seller discounts a payoff from the second period trade by the discount factor δ_s; the buyer's discount factor is δ_b. These discount factors are common knowledge.

FT showed that in this game there is a unique PBE. First, let us consider the PBE when the seller is soft in the one period game. If the first period offer has been rejected the seller will always offer $p_2 = \underline{b}$ in the second period. From above, all types will accept such an offer.

Anticipating the second period price, the high type will only purchase the item in the first period if:

$$\overline{b} - p_1 \geq \delta_b(\overline{b} - \underline{b})$$

or if:

$$p_1 \leq \delta_b\underline{b} + (1 - \delta_b)\overline{b} = \widetilde{b}.$$

Considering the strategies of the potential buyers the seller must decide between offering two different prices in the first period: $\underline{b}$ or $\widetilde{b}$.[†] The seller chooses the

[†] $\widetilde{b}$ dominates any price between the interval $(\underline{b}, \widetilde{b})$ because the same number of customers purchase the good at a higher price.

price with the larger payoff: if the seller charges $\underline{b}$ she sells to everyone and her payoff is $u_s(\underline{b}) = \underline{b}$; if the seller offers $\widetilde{b}$ in the first period her expected payoff is $u_s(\widetilde{b}) = \frac{1}{2}\widetilde{b} + \frac{1}{2}\delta_s\underline{b}$.†

Now consider a seller who is tough in the one-period game. With 2 periods this seller has three choices for the price she will offer in the first period. First, if a tough seller sets $p_1 = \underline{b}$ both types of buyer will purchase the good in the first period as above, and the utility of the seller is $u_s(\underline{b}) = \underline{b}$.

Second, the seller realises that a type $\overline{b}$ buyer will buy in the first period regardless of the seller's second period strategy if $\overline{b} - p_1 \geq \delta_b(\overline{b} - \underline{b})$, or if $p_1 \leq \widetilde{b} = \delta_b\underline{b} + (1-\delta_b)\overline{b}$, as the buyer cannot expect to make a larger gain in the second period (the seller would never offer a price less than $\underline{b}$). Thus if the seller offers $p_1 \leq \widetilde{b}$, a type $\overline{b}$ buyer will accept with probability 1.† Given the high types accept this offer the seller will offer $p_2 = \underline{b}$. If the seller plays this strategy her expected return is $u_s(\widetilde{b}) = \frac{1}{2}\widetilde{b} + \frac{1}{2}\delta_s\underline{b} = \frac{1}{2}(\delta_b\underline{b} + (1-\delta_b)\overline{b}) + \frac{1}{2}\delta_s\underline{b}$.

Finally, consider the mixed strategy of the buyer $\overline{b}$ if $p_1 > \widetilde{b}$. The mixed strategy equilibrium requires that: (a) enough buyers with value $\overline{b}$ do not purchase the good in the first period so as to make the seller indifferent between playing soft or tough in the second period; and (b) the $\overline{b}$ buyer must be indifferent between purchasing the good in the first or second period.†

In the two period game a seller who is tough in the one-period game can choose from either of the three separate strategies outlined above: the optimal strategy will depend on the relative payoffs of the three alternative strategies.

Several important economic issues arise from this model. In a similar manner to the one-period model, the buyer's private information may result in trade being

†Thus the PBE is as follows: the (soft) seller offers either $\widetilde{b}$ or $\underline{b}$ in the first period. Her beliefs are $Pr(b = \underline{b}) = \frac{1}{2}$ in the first period and that $Pr(b = \underline{b}) = 1$ in the second period if $p_1 = \widetilde{b}$ (and this offer was rejected.) A buyer with valuation $\underline{b}$ will accept offers of $p_t \leq \underline{b}$ in both periods with probability 1 and $p_t > \underline{b}$ with probability 0 in both periods. Buyers with valuation $\overline{b}$ will: accept $p_1 \leq \widetilde{b}$ with probability 1 and reject all other offers; accept offers in the second period provided $p_2 \leq \overline{b}$ with probability 1; and will accept offers $p_2 > \underline{b}$ with probability 0.

†As before, a price of $\widetilde{b}$ dominates an offer of any other price between $\underline{b}$ and $\widetilde{b}$.

†The buyer can satisfy these conditions by setting a price in the first period arbitrarily close to $\overline{b}$ ($p_1 = \overline{b} - \varepsilon$) and playing soft in the second period with a probability arbitrarily close to zero.

delayed or it may not occur at all. Further, the introduction of a second bargaining period may increase or decrease welfare (relative to the one period model). Inefficiency can arise when a type-$\bar{b}$ buyer rejects an offer they would have accepted in the one-period game.

The seller may be made better off by the addition of bargaining periods as it may allow her to extract surplus from the high valuation buyer without losing the chance to sell to the low valuation buyer. For example, a soft seller has to be at least as well off by the addition of a bargaining period, as she could always charge $\underline{b}$ in both periods. However, a seller who is tough in a one-period model may be made worse off by the addition of a bargaining period. In the one period game no buyer has positive surplus so the addition of a bargaining period cannot make a buyer worse off.

Overall, FT concluded that the implications of the changing the bargaining process and the characteristics of the players are not always clear and need to be examined for each specific bargaining game.

Sobel and Takahashi (1983) developed a very similar model in which a seller makes offers to a buyer whose valuation is private information. If the buyer accepts the offer, trade takes place at that price. If the offer is rejected, the bargaining process proceeds to the next period. The bargaining game has at most T periods and delay is costly for both the buyer and seller.

Again, delay may arise in equilibrium as a consequence of the buyer's private information. Another major focus of their paper is the effect of the seller's ability to commit to a pricing schedule over the T periods. This is compared with the situation in which the seller cannot commit to adjust her offer price given the history of the game (using the information she has learned about the buyer's valuation from his rejection of previous offers). When commitment is possible the seller determines the pricing schedule that maximises ex ante surplus. Without commitment the price offered in any period must maximise expected surplus given the information that the seller has learned about the buyer from his refusals of all previous offers. Thus without commitment the buyer's strategy conveys information to the seller.

This inability to commit to a pricing schedule hurts the seller (ex ante). As in FT: increasing the length of the bargaining horizon may not necessarily improve the welfare of either the buyer or the seller; and making one player more impatient does not necessarily improve the welfare of the other bargainer (when commitment is not possible).

Result 2.4 summarises the discussion above of the implications of private information in one-sided offer models.

Result 2.4 *Delays in bargaining can result from the introduction of one-sided private information. Moreover, with private information, increasing the number of potential bargaining periods does not necessarily improve welfare.*

Other papers have made further extensions to the basic one-sided offer model with one-sided asymmetric information. For example, Fudenberg, Levine and Tirole (1987) developed a model in which the seller can make offers to a buyer whose value for the good is private information. In addition, however, the seller can take up an outside option. They examined both the case in which the seller can switch to a new buyer at a cost and the case where there is a time cost involved in switching to another party. Different equilibria are possible, including equilibria in which the seller haggles with the buyer for a finite period of time before switching to the outside option. This result occur even when it is common knowledge that there are potential gains from trade. That is, bargaining ends after a fixed number of periods even when there are potential gains from trade remaining. Moreover, the introduction of outside options does not necessarily increase total expected surplus.

Crampton and Tracey (1992) modelled a union and a firm bargain over a new wage claim. The union makes all the wage offers and the firm has private information regarding their willingness to pay. In addition to the basic model, in the event of a dispute over a wage claim, the union can either choose to strike or 'holdout'. A holdout is defined as continuing to work (for that period) according to the conditions of the expired contract.† The authors presumed that the return to the union (and

†Crampton and Tracey argued that holdouts are a common occurrence in actual labour contract negotiations.

the firm) is larger from a holdout than from striking, although total surplus is reduced if a new agreement is not signed. In their model equilibria exist in which the union chooses to holdout in the event of a refusal of a wage offer by the firm rather than strike. Note, as it is inefficient, holdout is still a form of delay. Gu and Kuhn (1998) extended this model to incorporate the idea that by refusing to reach agreement (delay) a union can observe other wage outcomes in their industry. If the profitability of firms in an industry are correlated, there is an incentive for a union to delay its negotiations in order to learn about the firm's ability to pay from other wage deals in the sector.†

2.3.2 Alternating-offer models with one-sided asymmetric information

Rubinstein (1985) and Osborne and Rubinstein (1990) developed a model with one-sided asymmetric information with sequential alternating offers. As in Rubinstein (1982) two players must agree on the division of a cake of size 1. Player 1's utility is represented by $u_1 = x_1 - c_1 t$, and this is common knowledge. He makes an offer to player 2 whose utility function is $u_2 = x_2 - c_2 t$, where c_2 can either be c_H or c_L, $c_L < c_1 < c_H$ and $c_L + c_1 + c_H < 1$. c_2 is private information: player 1 is unaware of its value. Player 1's prior is that $c_2 = c_H$ with probability π_H and that $c_2 = c_L$ with probability $(1 - \pi_H)$.

If player 2 accepts 1's offer, the game ends and the cake is divided as agreed. If the offer is rejected the game proceeds to period $t = 1$ in which it is player 2's turn to make a proposal to player 1. If player 1 accepts the payments are made and the game ends. If player 1 rejects this proposed division the game continues, it is again player 1's turn to make an offer. This structure of alternating offers is the same as the original Rubinstein (1982) game. The first 2 rounds of the bargaining game are

†Kuhn and Gu (1999) developed a similar model in which there was a sequence of union-firm bargains. As above, the profitability of the firms are correlated. Consequently, the outcome of the preceding negotiation allows unions in subsequent negotiations to learn additional information about the firm they are bargaining with. Canadian panel data supports their prediction that there will be fewer strikes in 'follower' wage negotiations as compared with 'leader' negotiations.

shown in Figure 2.5.

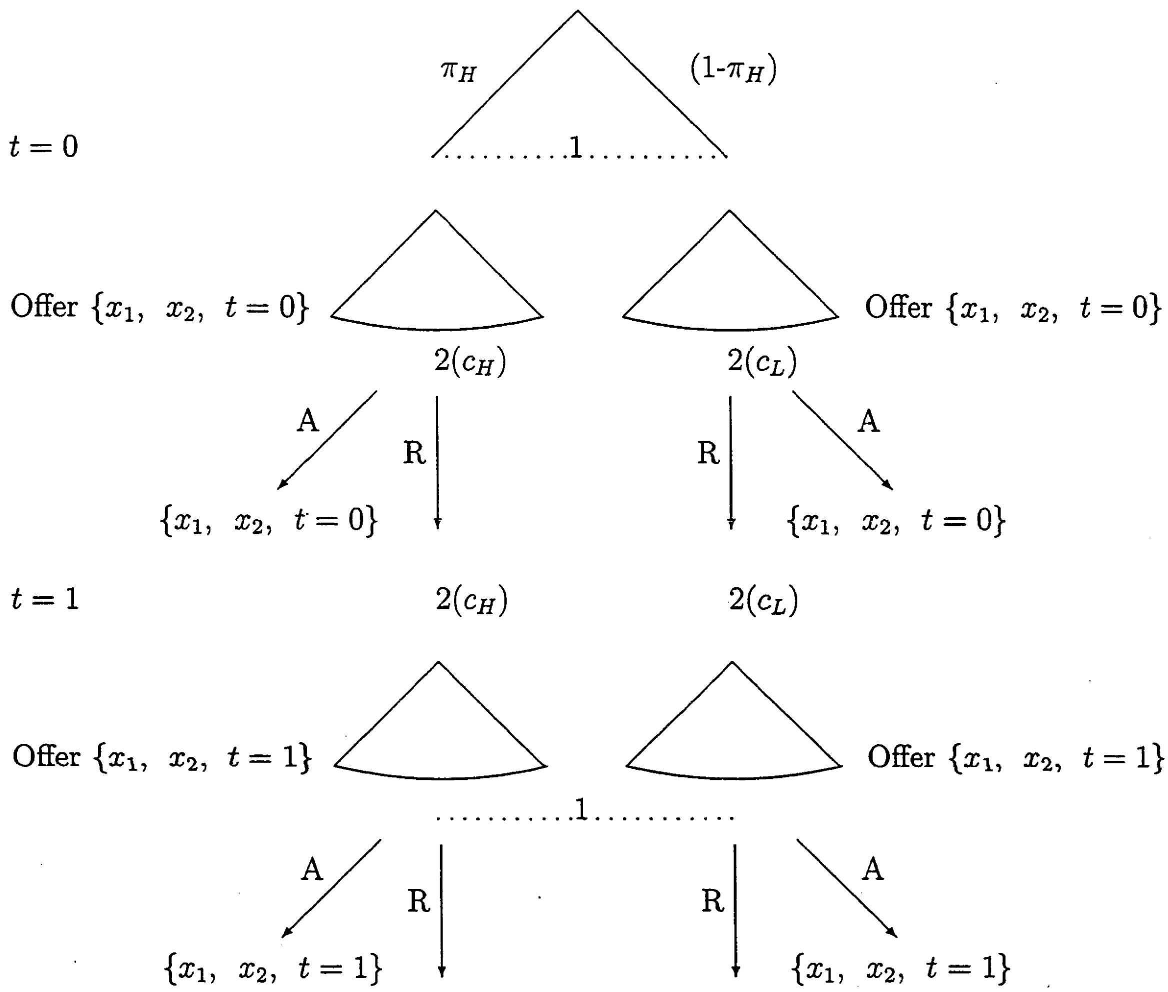

Figure 2.5: Alternating offer game with one-sided private information

Osborne and Rubinstein showed that there are multiple sequential equilibria in this game as little restriction is placed on player 1's off-equilibrium path beliefs. However, a set of equilibria in which the players play stationary strategies involves player 1 making a proposal that is accepted by player 2 if she is a high cost type (that is she has $c_2 = c_H$) while it is rejected by low cost types. The continuation game (after period $t = 0$) is now effectively one of complete information. As shown by Rubinstein (1982) there is no delay in this bargaining game with full information - in period $t = 1$ player 2 (with $c_2 = c_L$) makes an offer and player 1 immediately accepts. Consequently, this set of equilibria involves a delay when player 2 is a low cost type, but only for one period.

To generate delays in negotiations that last for longer than one period Osborne and Rubinstein (1990) allowed the strategies of the parties to depend on the bargaining period. Consider the following strategy profile: each player proposes that they receive all the surplus whenever they make an offer in every bargaining period t, provided $t \leq T$; further, prior to period T each player only accepts an offer that gets them the entire surplus and they reject all other offers. After period T, however, the strategies change and each player makes an offer that is immediately accepted. These strategies form an equilibrium because any deviation by a party (that is, if they make an alterative offer) will be punished by the other party with all their future offers. Provided T is small enough, both players find it better not to deviate from this strategy and a delay in agreement of T periods is observed in equilibrium.†

Result 2.5 summarises the main points of this section concerning delays in bargaining.

Result 2.5 *In an alternating-offer model in which player 2 has private information, delays in agreement can result in equilibrium.*

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†See section 2.3.3 for a further discussion of this model.

2.3.3 The Coase conjecture and protracted delays

Gul and Sonnenschein (1988) and Gul, Sonnenschein and Wilson (1986), hereafter GSW, argued that bargaining models with one-sided asymmetric information, like those discussed above, fail to explain protracted delays in agreement. This proposition is also known as the Coase conjecture. Their result relies on the assumption that each player's action should depend on their beliefs (or on the beliefs of the uniformed party) and not on the period of the game; that is, strategies should be stationary. This, for example, is not the case in Osborne and Rubinsteins' (1990) non-stationary strategy equilibrium above. In that equilibrium the players alter their strategies in period T even though no information has been revealed along the equilibrium path. According to GSW, if no information is revealed to the uniformed party their beliefs should remain unaltered, and they should continue to play the same action. Further, GSW assumed that there is no free screening: the uniformed party does not learn any information about which type she is facing after a rejection of an offer if both (all) types would reject the offer. If these assumptions hold agreement is reached no later than the second period in the game of Osborne and Rubinstein (1990).† Further, as the time between periods becomes arbitrarily small, the time lapsed before agreement is reached becomes small, as does the cost of delay (Sutton 1986).†

Several authors have attempted to overcome this critique, as outlined below.

Hart (1989)

Hart (1989) developed a model to explain the observation that many strikes last for an extended period of time. His model incorporates two assumptions. First, there is a finite time period between offers. That is, the time lapse between, say, period $t = 0$ and period $t = 1$ cannot tend to zero in the limit. Second, after the

†See the game where the parties were forced to play stationary strategies in section 2.3.2.

†Muthoo (1999) argued that the Coase conjecture implied that, in the limit, as the time between offers approaches zero all potential gains from trade are realised without any costly delay and that the uniformed party making the offers effectively loses almost all of the bargaining power typically associated with being the party that gets to make the offers (Property 9.2 p. 280).

strike has lasted for a certain number of periods, in each subsequent period in which the strike is not resolved there is a fixed probability that the profitability of the firm declines to zero. If this occurs bargaining ceases.

A firm can either be a low profit or a high profit operation; each type occurs with known probability. The union (the uniformed party) makes wage offers to the firm in each period until an offer is accepted by the firm. To this model Hart adds the assumption that after a certain period of time T there is some probability that the firm with a striking workforce becomes valueless. Each party incurs a cost of delay as each discounts the future.

Hart found that, provided the profit of the high profit firm is large enough, bargaining will extend beyond period T. The advantage to the union of delaying agreement until after this point is that the probability of the firm becoming unprofitable reduces the union's effective discount rate, making the post-T period game more attractive to the union. The union, as such, must weigh up the cost of delaying agreement until period $T + 1$ with the potential benefits of doing so. For some parameter values the union wishes to delay, and a protracted disagreement occurs in equilibrium.

Admati and Perry (1987)

Admati and Perry (1987) developed a model in which parties can signal their bargaining strength by choosing how much time should lapse before they make a counter offer (after a minimum delay has passed as in the standard alternating offers game). Unlike other bargaining games this model allows the time between offers - delay - to be endogenous.

Suppose that in a union-firm bargaining game only the firm has private information and that the union makes the first offer to the firm (the union is the uniformed party). If the firm is in a strong bargaining position, and it does not wish to accept the union's first offer, one option for the firm is to delay making its counter offer to signal its strength. In a similar manner to the signalling models of Spence (1973), the delay in response must be of such a length that it indicates strength;

the delay must be of sufficient duration that it would never pay a firm in a weak bargaining position to delay negotiations for such a long period. From this point on the game becomes one of full information and the union accepts the firm's offer without further delay.

In this bargaining game long delays may exist even when the minimum time between offers tends to zero. This model, however, has the unusual characteristic that the period of delay involves the parties remaining silent and not making any offers.

Hart and Tirole (1988)

Hart and Tirole (1988) considered the long-term relationship between a seller of a durable good with a buyer whose valuation of the good is private information. For simplicity they assume that the buyer's per period valuation is either low ($\underline{b}$) or high ($\overline{b}$). It is known that the probability that the buyer has a valuation of $\overline{b}$ is μ. With one-sided offers, the seller makes price offers to the buyer. If the buyer agrees, the parties trade according to the contract. If agreement is not reached, the parties receive the no-trade payoff (of zero) and proceed to the next period, provided that period was not the end of the game.

Hart and Tirole considered several different situations. First, they showed that when commitment was possible, the solution in the game is that the seller sets her optimal price, be it a sale or rental price. If $\underline{b} < \mu\overline{b}$, the seller sets price equal to $\overline{b}$ at each point in time. As a result, she only sells to the high-valuation buyer in every period. Second, the authors considered when commitment was not possible. In this case, if a buyer accepts a price for the good in one period that reveals them to have a value $\overline{b}$, the seller will renegotiate price in the next period. Realising this potential loss will last for the rest of the game, consumers with a high valuation will not be willing to reveal their type if there is a sufficient number of periods remaining. Given this, the seller will set the price at $\underline{b}$ until near the end of the game when screening becomes feasible. As a consequence of the lack of commitment, price is low for many periods, say for K periods, after which time the price jumps when the seller starts to screen the high-valuation types from the low types.

This contradicts the Coase conjecture. Coasian dynamics suggest that prices are monotonic across time and that the player with a high value of the good trades earlier: in other words, over time the price falls and after a time everyone consumes the good. The equilibrium path in the model of Hart and Tirole (1988) is non-Coasian: price remains low for a long time, and everyone consumes the good; after a given point in time the price increases, forcing some buyers out of the market.

Result 2.6 summarises the main points of the models discussed in this section.

Result 2.6 *The Coase conjecture suggests that models with one-sided asymmetric information are unable to explain protracted delays in bargaining. Several models, however, overcome this critique by: considering strategies that are non-stationary; allowing the bargaining game to alter after a period of delay; when commitment is not possible; and allowing the length of delay to be endogenous.*

2.3.4 Two-sided incomplete information

An obvious extension of bargaining models with one-sided private information is to allow both parties to possess private information. Kennan and Wilson (1993) described bargaining models with two-sided asymmetric information as a 'war of attrition' in which each party tries to out last the other. At some point in time, one party will decide that their cost of delay is greater than the cost of the other party and they will concede. For example, in a model described by Kennan and Wilson (1993) each party has a fixed cost of delay per time period. When a party concedes, the game resembles Rubinstein's (1982) alternating bargaining game with fixed costs: agreement is reached immediately, with the division of surplus as described by Rubinstein (1982). Perry (1986) found a similar results hold when the parties know each other's cost of delay but possess other private information.

Crampton (1984) extended the models of Fudenberg and Tirole (1983) and Sobel and Takahashi (1983) by considering an infinite horizon bargaining model, with two-sided incomplete information in which one party makes all the offers. In the equilibrium, information is revealed gradually over time and the rate of revelation depends on the players' costs of delay. The results of the model are that: incomplete information leads to bargaining inefficiency; these inefficiencies increase as uncertainty about preferences increases; bargainers with high delay costs are at a disadvantage; and information is revealed more quickly the higher the costs of delay.

Other authors find similar results. Chatterjee and Samuelson (1987) develop an infinite horizon alternating offer model with two-sided asymmetric information.[†] They find that the sequential equilibrium in the game is unique. This result holds because strategies that require an element of commitment are not credible. Further, the model has the implication that a player in a stronger bargaining position is more likely to have a larger claim on the surplus. Watson (1998) showed inefficient equilibria exist in an infinite horizon alternating-offers model with two-sided asymmetric information. Further, he derived the result that a player does not gain a larger share of surplus from a small chance that they are a strong type but that they can be hurt significantly if there is a slight chance that they are a weak agent.

2.4 Symmetric information and delays in bargaining

The models described in the previous section implicitly assume that, if there was no asymmetric information between the parties, there would be no delays in bargaining (Avery and Zemsky 1994a). This assumption is evident in that there is no delay in any continuation game with complete information. The papers reviewed in this section attempt to generate delays in bargaining in equilibrium when both the parties have symmetric (and possibly complete) information.

Complete information and history-dependent strategies

Haller and Holden (1990) extended the basic Rubinstein model by including the decision to strike as a strategic variable. In the first period a firm makes a wage offer to a union. If the union accepts the game ends. If the union rejects the offer,

[†]Also see Chatterjee and Samuelson (1983).

the union must decide whether to strike or not. If the union strikes it receives a payoff of zero, as does the firm. If the union does not strike it receives its wage according to the old contract. The parties forgo the increase in surplus, however, if they do not reach agreement in that period. If the firm's offer was rejected in the first period, in the second period the union makes another offer. Again, if its offer is rejected the union, can opt to strike or not to strike. This process continues until agreement is reached. The parties have perfect information.

One equilibrium in this game is the Rubinstein equilibrium.† However, other equilibria are also possible. The lowest payoff the union can receive in equilibrium is to receive a wage equal to its default payoff. This will occur when the union never strikes. If the union strikes only after rejections of its own proposals it will receive a payoff greater than the Rubinstein payoff; this is the maximum payoff the union can achieve.

Haller and Holden (1990) showed how these multiple equilibria can be used to generate delays. Consider the following strategy. For t periods both players offer divisions that allocate all the surplus themselves. These offers are all rejected by the other player. If a player deviates to make a more generous offer, this player is punished by the other player who switches to play the worst efficient equilibrium for the deviator from that period on. It is the threat of punishment, that can only arise with multiple equilibria, that prevents a player from deviating and making an alternative offer. After t periods an offer that is acceptable is made and the other player accepts. As a result of this type of strategy, strikes of significant length arise, despite complete information.

Fernandez and Glazer (1991) developed a similar model. As in Rubinstein (1982) two agents - a union and a firm - bargain sequentially in discrete time over a potentially infinite horizon. Each party takes it in turns to make a wage offer that the other party can accept (and terminate the bargaining process) or reject and continue bargaining. In addition to the basic model there is an old wage contract that continues to apply if an offer is rejected. Thus, if an offer is rejected the union

†This occurs when the union strikes after every rejection.

can decide to strike in that period or to continue to work at the wage specified in the default contract. If a strike occurs, the union forgoes the wage in the default contract and the firm forgoes the new revenue in that period. As usual, each party discounts future returns, and each party's objective is to maximise discounted returns (surplus).

In a similar manner to Haller and Holden (1990), an inefficient SPE equilibrium can take the following form. The union makes very high wage offers that are rejected by the firm. Similarly, the firm makes very low wage offers that are also rejected by the union. In each of these periods the union then chooses to strike. This continues (in equilibrium) for T periods. After T periods, a proposition is made that is between the high and low wage offers made in the delay periods and this is immediately accepted. In equilibrium no party wishes to deviate, despite the loss in surplus, because any deviation before period T is punished thereafter by the other party who will play an efficient strategy in every subsequent period, but one that adversely affects the deviant.[†] As the total time of inefficient bargaining, T periods, can be of substantial length, Fernandez and Glazer argued that the model can sustain significant delays in agreement (strikes) as part of an equilibrium strategy.

Busch and Wen (1995) developed a similar model. In their model two players make alternating offers for a stream of surplus. If an offer is accepted the parties forever share in the flow of surplus in accordance with the agreement. If an offer is rejected, before another offer is made, the two parties play a one-shot game, known as a disagreement game, to determine their current payoffs. The parties cannot contract on moves in this disagreement game. Following the disagreement game, the other player makes an offer, and so on. This process continues until an agreement is reached. Again, the parties have perfect information. The payoff to each player is the sum of their disagreement returns plus their agreement share of surplus, all appropriately discounted. To a degree, the authors have combined the

[†]Note, these history-dependent strategies have similarities to the non-stationary strategies in Rubinstein (1985) and Osborne and Rubinstein (1990) although there is complete information in this model. Further, in a similar manner to the trigger-strategy equilibria in infinitely repeated games, deviation is not observed in equilibrium because it will trigger a punishment phase.

alternating-offer bargaining game of Rubinstein with a repeated game.

There are several important elements of the model. The first is that the parties can play history-dependent strategies. Second, the inclusion of the disagreement game can allow these history-dependent strategies to have an effect on the outcome of the game in that a party can be 'punished' from deviating from a proposed equilibrium path, in much the same as a party can be punished for a deviation in an infinitely repeated game.[†] Provided the disagreement game satisfies certain conditions, there are multiple perfect equilibria, some of which involve inefficient delay.[†]

Avery and Zemsky (1994b) developed a model to capture the common elements of other papers that involved multiple equilibria, delay and threats to reduce total surplus. They noted that in all models of this sort there are multiple equilibria with immediate agreement. It is the threat that a player will receive their worst equilibria payoff that prevents them from making an acceptable offer.

They developed an alternating-offers model in which whenever player 2's offer is rejected she has the option to decrease that period's non-agreement payoffs or increase the discount factor that applies for that period. The authors term this ability to reduce surplus 'money burning'. Although a Rubinstein equilibrium with no money burning and immediate agreement always exists, provided player 2 can profit from burning money, equilibria involving delay are possible. As above, in these equilibria, both players demand the entire share of surplus when making an offer and refuse to accept any similar offers from their opponents. Any offers that deviate from this path are punished by reverting to the worst equilibrium payoff for the deviator. This will be sustained in equilibrium for t periods, provided that t is sufficiently small. After time t offers revert to an intermediate share of the surplus

[†]In the standard Rubinstein game, history-dependent strategies are ineffectual as, given the stationarity of the game, a punishment can only return the parties to identical situation, at a later point in time.

[†]Although this result is similar to the folk theorem with infinitely-repeated games, Busch and Wen (1995) noted that the set of possible equilibria is smaller than the potential set of equilibria in the disagreement game. This is because the alternating-offers bargaining aspect of the game requires the rewards from playing non-Nash strategies in the disagreement game must follow immediately given the stationarity of the game.

and agreement is reached.[†]

In a somewhat different context, In and Serrano (2000) explored bargaining between two parties over several issues. The parties need to accomplish two things: first, they need to set an agenda to determine the order in which the issues are to be discussed; and, second, they need to resolve each individual issue. The authors considered an alternating-offers bargaining procedure that only allows one issue to be resolved at a time. Player 1 would make an offer on one, but only one, of the remaining issues. Player 2 could then either accept or reject this offer. If she accepts the issue is resolved and it is the respondent's opportunity to make an offer concerning one of the remaining issues. If Player 2 rejects player 1's offer there is a probability that negotiations will breakdown. If this occurs the game ends. If this does not occur, the game continues and player 2's makes an offer on one of the remaining issues. As the players set the agenda, the order that the issues are examined is completely endogenous. Further, there is complete information in the model.

The bargaining procedure itself contains an inefficiency in that the parties are unable to exploit the trade-offs in the marginal rates of substitution between these issues. This inefficiency is accentuated, however, by a large number of non-stationary equilibria, some that involve arbitrarily long delays.[†]

Manzini and Mariotti (1997) examined the effect of an arbitrator on the outcome of an alternating-offers model. As usual, player 1 makes an offer over the division of surplus. If player 2 accepts this offer the game ends. If she rejects the offer she can propose that the parties discontinue bargaining and opt for the arbitrator. If the other player agrees to take up this option, the arbitrator divides surplus in a

[†]Manzini (1997) developed a model in which upon rejection of a union's offer, the union takes an action that reduces the size of the surplus to be bargained over permanently (that is, surplus in subsequent periods will be less than 1). In a similar manner, Manzini (1999) allowed the union to be able to choose to reduce the total surplus permanently after one of its offers has been rejected. Although this destructive power allows its possessor to increase their share of surplus, as it does not generate multiple equilibria, it cannot sustain delays in equilibrium.

[†]In and Serrano (2000) argued that the multiplicity of equilibria was indicative of a wide range of opinions about which items should be discussed first. Disagreement in their model cannot be indefinite, however.

predetermined manner and the game ends. Note, it is costly to use the arbitrator (surplus is greater if the parties can agree on a division by themselves) and both players know the payoffs they will receive from arbitration (neither party can be tricked into accepting arbitration under false pretences). Further, arbitration can only be engaged by mutual consent. If player 2's proposal of arbitration is rejected, or if she chose not to exercise it, she then makes a proposal of how to divide the surplus to player 1 in the normal manner. The game continues until agreement (or an arbitrated outcome) is reached.

Although arbitration is never enacted in equilibrium, the authors find that it can dramatically affect the outcome of the bargaining game. For example, the outcome of the game is exactly the arbitrated outcome (given arbitration costs are sufficiently small) no matter what this outcome is. When players can play non-stationary strategies, the presence of arbitration can generate delays in bargaining. Again, arbitration is never enacted in equilibrium, however, off-the-equilibrium path strategies involving the arbitrator can sustain costly delays in bargaining.[†]

Delays and externalities

Jehiel and Moldovanu (1995a) developed a model in which delay may occur before trade takes place due to identity-dependent negative externalities between the parties.[†] In the model a seller has an indivisible good that she can sell to one of N potential buyers in any of the T bargaining periods. In any period the seller randomly meets one of the potential buyers. At this point the seller can make an offer to that buyer but not to any of the other buyers. The seller is free to make an unreasonable offer. This is equivalent to the strategy of making no offer at all. After an offer has been made to the nominated buyer, this buyer has the option to accept or reject the offer. If the offer is accepted trade takes place. The seller's

[†]McKenna and Sadanand (1995) explored an alternating-offer model in which an arbitrator would be enlisted at time T if agreement had not been reached. They found that delay could occur until the arbitrator was called upon if the two parties had sufficiently different beliefs about how the arbitrator would distribute surplus.

[†]Jehiel and Moldovanu (1995b) also examined delays in bargaining in the presence of externalities.

return is the price p. The buyer's surplus is his value of the item net of the price paid. If trade takes place, the other potential buyers incur a loss that is specific to the identity of the buyer. This is typically a negative externality, although it could be zero in some cases. If the offer is rejected, the game proceeds to the next period unless the period was the last period of the game, in which the game ends. The game ends after T periods even if agreement has not been reached. Provided it is not the end of the game, in the period following a rejection a buyer is once again randomly paired with the seller, and the bargaining process is as described above.†

In this game both the buyer and seller may be willing to delay agreement, and these delays may reduce total ex ante surplus. As an illustration, consider the following example taken from Jehiel and Moldovanu (1995a). Assume there are three potential buyers. Buyers 1 and 2 value the good highly, but they will incur a large cost if the item is purchased by buyer 3: they will both incur an external cost of either of them purchases the item, but not as large as if buyer 3 gets the good. Buyer 3 does not value the good as highly as buyer 1 or 2, and will not suffer any external cost no matter who purchases the good.

For the seller, buyers 1 and 2 are more attractive than 3 because not only do they value the item more highly, they are also concerned about suffering an external cost if buyer 3 purchases the item. The seller may wish to delay making a reasonable offer until near the end of the bargaining process so as to make the threat to sell to buyer 3 credible. Buyers 1 and 2 will be unwilling to pay the high price until closer to the end of the game because each of them hopes that the other will purchase the item (at the high price) and save them from buyer 3. It is only when the threat that the seller may have no other option than to sell to buyer 3 (because the end of the bargaining horizon is approaching) that either 1 or 2 will find it worthwhile

†The structure of the game is motivated by bargaining situations such as when different television stations bid for the exclusive telecast rights of special event, like the Olympics. Each station may value the rights of this special event differently. The stations that do not end up getting the exclusive rights will suffer as their viewing audience will be reduced. Further, this negative externality will depend on which station acquires the rights, as this determines which of the normal programs will be taken off the air. Not all stations will be affected the same, however, as each will have different abilities to compete with the special event. Consequently, the negative externality incurred by stations from the transaction are identity dependent.

to endure the high offer price. Buyers 1 and 2 will also delay buying the item in a 'war of attrition' in the hope that the other buyer buys the item instead and saves them from buyer 3 (and the high price demanded by the seller).

Jehiel and Moldovanu (1995a) noted that delay in their model does not directly relate to inefficiency. However, delay may be associated with a loss in total expected welfare for certain parameter values (of the private benefit and external costs) as there is a positive probability that the item will be sold to the 'wrong' consumer, for example buyer 3 who has a low value of the item and who generates a high external cost.

Frankel (1998) examined a bargaining model in which both parties have the opportunity to search for new ideas that enhance total bargaining surplus: the externality arises as both parties can benefit from one player's effort. He considered two separate models. First, players can make side payments as part of the bargaining process. In this variant of the model player 1 could make an investment that increased the total size of the surplus before entering into an alternating-offers bargaining game with player 2. Given that player 2 captures part of the return from player 1's investment, there is underinvestment in creative effort by player 1. This result is similar to the underinvestment result of the hold-up literature.[†] Second, Frankel considers when side payments are not allowed (that is, utility is not transferrable and no compensation can be paid). In this case both partes can invest in efforts to increase total surplus, however, they strategically restrict their search to ideas that benefit them. This imposes a negative externality on the other player. There is, however, a positive externality if only one player comes up with an idea. Frankel finds that when a player can effectively narrow her search to ideas that give her a large share of surplus, there is excessive effort investment in this kind of selfish search activity. When the positive externality dominates there will be suboptimal investment.

[†]Depending on the specific assumption concerning the timing of the creative effort, there can be an inefficient premature agreement or excessive delay. In either case, however, surplus is not maximised.

Option values and uncertainty

Avery and Zemsky (1994a) examined the effect of uncertainty on delays in bargaining. In their modified alternating-offer game, the two parties bargain over the distribution of surplus from the sale of an asset, the value of which is affected by exogenous shocks over time.

In each period the value of the asset incurs a positive or negative shock, and this shock is observed by both parties via a dividend price for the asset in that period. Throughout the game the parties have symmetric information, despite the uncertainty about impending shocks. Further, although the shocks are random, the authors assume that in the long run the expected value of the asset is unaffected by these temporary shocks. Once again this is common knowledge.

The timing of the game is as follows. In any period, one of the parties makes an offer to sell the asset at a certain price to the other party. After the offer has been made, an exogenous shock affects the value of the asset and the impact of this shock is revealed to both parties. It is assumed that the offer price cannot be contingent on the new information about the asset (an assumption that is common place in the incomplete contracts literature). After observing the shock, the second party may accept or reject the offer. If the offer is accepted trade occurs at the agreed price. If not, the opportunity to trade in that period is lost (reducing the total available surplus) and the game proceeds to the next period in which the roles of the players is reversed. As a result of the timing of the new information about the asset, any offer can be treated by the responding party as an option value that may be exercised if it is needed. This can act to reduce the offers made by the first party.

Delay may occur when players make offers that will only be accepted for some asset value realisations (termed 'separating offer delay'). Avery and Zemsky find that if this sort of equilibrium exists it is unique. Alternatively, players may 'wait' several periods by offering a sequence of unreasonable prices (regardless of the arrival of the new information in the form of the dividend prices in those periods). These offers are not accepted by the responding party. After a finite number of periods, as in Fernandez and Glazer (1991), an acceptable offer is made and accepted. The authors found that if a separating offer delay equilibrium does not exist, there are multiple equilibria provided the uncertainty about the asset value is sufficiently great.

Result 2.7 summarises the propositions made in the models discussed in this section.

Result 2.7 *Delays may arise when the bargaining parties have symmetric information: if parties play non-stationary strategies in which deviations can be credibly punished; in the presence of party specific externalities; and if the parties are uncertain about the future value of the surplus and are unable to write contingent contracts.*

2.5 Conclusion

This chapter provided a selective review of non-cooperative bargaining models and, in particular, their explanations of why costly delays occur. Delays in bargaining arise in equilibrium because of: incomplete information (both one-sided and two-sided); the presence of uncertainty; or because of the presence of some market failure such as externalities. The discussion also touched on other elements of these models that will be relevant in the new explanation of bargaining delay presented in the next chapter, specifically that: an outside options only affect the outcome of a bargain if they can be credible employed; and the ability to commit (to a particular offer for example) can potentially affect bargaining outcomes. The model in the next chapter provides a new explanation for delays in bargaining. Specifically, delays arise due to: an inability of the parties to commit to not renegotiation (incomplete contracts); wealth constraints; and there are multiple bargaining periods.

CHAPTER 3

Delays in bargaining with incomplete contracts

3.1 Introduction

One of the most dramatic industrial confrontations in recent times occurred between the newspaper proprietors and the print unions in the United Kingdom during the 1970s and 1980s over the introduction of photocomposition. This new technology allowed copy to be keyed into the computer, newspaper pages to be organised on a computer screen, then for the printing plates to be made directly from photographs of page bromides (Griffin 1983, p. 42, Martin 1981, p. 30). In terms of output, a linotype operator could set only seven column lines per minute whereas the new electronic typesetting technology increased this rate to 3000 column lines per minute. Given the tight deadlines of newspapers, this difference was very significant (Griffin 1983, p. 42). Photocomposition 'rendered obsolete many of the craft skills possessed by the compositor' as it 'removed the need for linotype machines and linotype operators' (Griffin 1983, p. 42).[†]

The introduction of photocomposition was vehemently opposed by the print unions, in particular by the National Graphical Association (NGA) that represented linotype operators who set the metal type. Initially the NGA rejected a proposal for 'frontloading', where journalists and salespeople typeset words directly without the use of printers. Another proposal was rejected by Fleet Street union members

[†]Also see Melvern 1986, p. 5.

in early 1977 (Willman 1986, p. 127). At *The Times* between November 1978 to November 1979 there was an industrial dispute over the introduction of new technology. The agreement that resolved this dispute, although establishing a style composing-room, was only a partial reform. Further, this dispute enhanced the monopoly position of the NGA at other titles such as the *Daily Express* and the *Observer* (Willman 1986, pp. 128-29). Willman (1986) stated that:

> Overall, therefore, the implementation of new technology in national newspapers has been substantially delayed by union resistance, in the form of strike action and of the imposition of costs (p. 129).

The dispute continued between the Rupert Murdoch, proprietor of the *Sun*, *News of the World* the *Times* and *Sunday Times* and the Fleet Street print unions in the 1980s. This dispute was only settled in January 1987.[†]

Why wasn't such an obvious surplus enhancing innovation made immediately? There are several important characteristics of this dispute. First, as the parties were in an on-going relationship it seems implausible that asymmetric information between the parties could result in a dispute over ten years long.[†] Second, as the parties were in a long-term relationship any new agreement could act to affect future claims on surplus. The introduction of photocomposition would reduce the NGA's bargaining power and control over the workplace as it was their specialist skills, and the restriction on supply, that distinguished its members from outside labour (Griffin 1983, p. 44). Third, knowing that innovation would reduce their claim on future surplus the print unions would require compensation for these losses. In this case it was difficult for the companies to provide adequate compensation. For example, in 1985 Murdoch's operation was so highly leveraged that the combined earnings of all his companies did not pay his interest bill (Melvern 1986, p. 6). This

[†]The eventual settlement with the unions was 60 million pounds. This is compared with Drexel Burnham's estimate that the value of Murdoch's four London papers rose from $300 million to $1 billion just by moving out of Fleet Street and that profits jumped 85 per cent (Shawcross 1997, p. 236). This suggests that the innovation clearly increased total surplus.

[†]In fact, it was Murdoch's secret printing plant at Wapping that helped resolve the dispute, ending the delay in the introduction of the new technology, rather than the reverse.

severely limited the amount he could borrow for compensation payments. Fourth, the parties were unable to write a contingent contract. The invention of the new technology necessitated renegotiation. Further, the labour market was subject to recurrent bargaining given the inability of the parties involved not to renegotiate (Willman 1983, p. 121).[†]

The model presented in this paper incorporates the above features to provide a new explanation for delays in bargaining. In the model two parties can choose to adopt a new innovation in each period of the game. (The basic model has two periods.) The innovation generates a known surplus that can be shared between the parties. Innovation, however, affects each party's claim on surplus in future periods. When an immediate innovation adversely affects a player's future payoff, that player will only be enticed to accept innovation if the immediate returns are sufficiently great so as to compensate her for these future losses. If this is not the case, the player will choose to delay, even if this reduces total surplus.

In the print union example above innovation reduced the future bargaining power of workers. The removal of a closed shop would have a similar effect. Alternatively, a party may wish to delay innovation when the existing contract provides a default payoff that it will lose if they agree to the change. That is, innovation changes the contract the parties use as a starting point for negotiations rather than altering the relative bargaining powers of the parties. For example, some workplace rules provide workers with on-the-job leisure.[†] By agreeing to change the workers lose their default (on-the-job leisure) payoff. This could reduce their claim on surplus in future negotiations.[†] In order to be induced to agree to change the union will need to be

[†]Also see Martin (1981) p. 96.

[†]Workpractices may involve: excessive demarcation; double handling; tea breaks or other idle time; the use of the same number of workers per machine despite the use of new or improved technology; limiting output either per worker or per machine; or requiring excessive overtime (Willman 1986, p. 54). Further, technical change may affect current working conditions, work allocation or the speed of work, all of which may affect an employee's surplus (Willman 1986, p. 47).

[†]The assumption here is that existing work arrangements affect the bargaining power of each party, and hence the distribution of surplus. Cornfield (1987b) suggested 'changes in labour relations arrangements reflect and contribute to the continuous redistribution of authority in the employment relationship and, therefore, to the capabilities of labour and management to guide their fortunes' (p. 5).

compensated for both current and future losses. If this cannot be achieved through an adequate compensation package or a credible promise of future payments, a union will decline to innovate, even if the change is efficient in the sense that it would increase overall surplus.

The different assumptions concerning how innovation affects the bargaining solution generate important alternative predictions. From the basic model, when innovation affects the default payoffs a party with a high default, is more likely to delay innovation. Further, delay is more likely when expected future surplus is lower. On the other hand, a party that loses its bargaining power when facing an innovation, as in the print union example, is also likely to oppose innovation. Given that it is more likely to face a specific innovation that reduces its bargaining power, a craft union is more likely to oppose change than a union with a broader constituency. In addition, a party facing an innovation that reduces its bargaining power is more likely to delay when future surplus is higher.

Some other recent models have explained delays in the absence of asymmetric information in different contexts. Jehiel and Moldovanu (1995a and 1995b) showed that there can be delays in the presence of party-specific externalities. Manzini and Mariotti (1997) introduced an arbitrator into an alternating-offers game with complete information, where the arbitrator can be called on by mutual consent. They find that, although never enacted in equilibrium, the mere presence of the arbitrator can result in delays. In Avery and Zemsky (1994a) there is symmetric uncertainty about the value of the bargain in the future. A party may wish to stall agreement in this situation as delay entails some option value. Last, Fernandez and Glazer (1991) showed that delay can arise in a model with complete information when parties play Pareto inefficient non-stationary strategies.

The paper is structured as follows. Section 3.2 outlines the model and section 3.3 describes the bargaining solution used. This paper uses the same reduced form bargaining solution as adopted by Chiu (1998); this bargaining solution is based on the infinite horizon alternating offer model with outside options of Shaked and Sutton (1982). In addition, the parties can make additional compensation payments subject to their limited funds. Section 3.4 explores the conditions necessary for delay when innovation alters the default payoffs of the parties and examines the comparative statics of the model. Section 3.5 investigates delay when innovation erodes bargaining power, as in the print union example. The predictions of the alternative models are outlined in section 3.6. Section 3.7 compares this new model with the literature. The model presented here has strong links to the hold-up literature. In the incomplete contracts literature a party may inefficiently (under)invest when they do not expect to receive the entire return from their investment.[†] In contrast to much of that literature, however, the innovation in this paper is cooperative in that it (potentially) generates a benefit for both players. Far fewer papers have studied the hold-up problem in the presence of cooperative investments, several notable exceptions being MacLeod and Malcomson (1993a), Che and Haush (1999) and Che and Chung (1999).

Section 3.8 extends the basic model in several ways: first, it extends the analysis to both a three period and an infinite horizon model; second, it reiterates how delay may arise due to the inability of parties to commit not to renegotiate; third, it discusses the implications for delay with specific and general investments (reform); and fourth, the section briefly discusses delay when there is more than one potential innovation in each period. Applications of the model are discussed in section 3.9. Finally, section 3.10 summarises the findings of the paper.

3.2 The model

This section outlines the model. There are two potential trading partners, denoted here as the buyer and seller. These parties may represent, for example, a worker or her representative (seller) and a firm (buyer), however, these terms should be interpreted in the broadest sense. All that is important is that they are two parties negotiating about the introduction of a surplus enhancing change in the relationship.

[†]See Grout (1984) and Hart and Moore (1988).

3.2.1 Timing

Figure 3.1 shows the time line of the model. There are two trading periods. At time $t = 1$ there is an existing relationship between the parties given by a default contract. This contract could merely describe the parties' existing relationship. Alternatively, it could represent a social norm or precedent. This pre-existing contract acts as the default contract for the parties, discussed below.

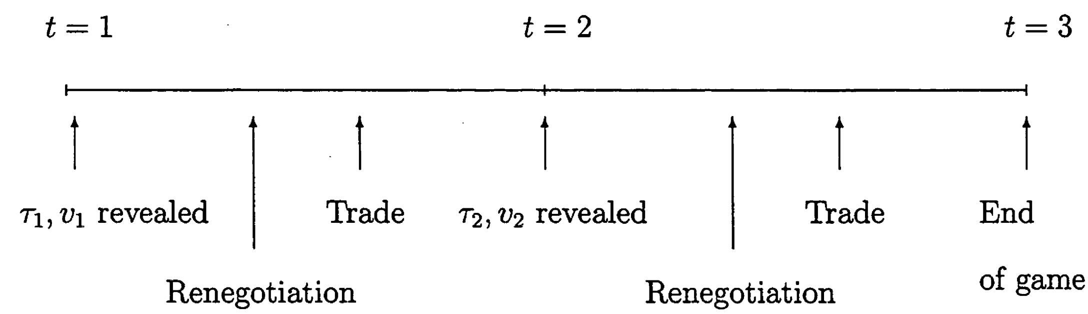

Figure 3.1: Time line of the model

At this point, an exogenous shock occurs. In the print union example this shock was the development of the new computer technology. As a result of the exogenous event it is revealed to both parties that if the seller performs task τ_1 surplus v_1 accrues to the buyer. Further, the performance of τ_1 is incompatible with the activity (and payoff) the seller receives under the default contract. For example, the default contract may involve some on-the-job leisure for the seller. The new task τ_1, on the other hand, could require the seller to work harder or at a constant speed. If the worker agrees to make the innovation she can no longer receive her default surplus.

After this information is revealed to both of the players, the two parties can renegotiate the initial (default) contract. The bargaining process is discussed in section 3.3, however, a new contract can only be implemented by mutual consent. After renegotiation, trade occurs according to the conditions of the existing contract (either the default contract if at least one party rejected change or according to the new contract if both parties agreed to innovate). Note also that neither party can be forced to trade if they would receive a negative payoff. After trade, each party receives their first period payoff.

The game then proceeds to the next period. This additional period captures the on-going nature of the relationship between the parties. The second period has the same structure as the first. The existing contract acts as the default for both parties. Once again, an exogenous event occurs. In light of this new information, it becomes apparent to the two parties that the performance of τ_2 by the seller generates surplus v_2 for the buyer. This is revealed to both parties and they can then renegotiate their default contract. After renegotiation, trade takes place according to the conditions of the relevant contract, the players receive their payoffs and the game ends.

3.2.2 Assumptions

Under the initial default contract at $t = 1$ the seller receives surplus of $b \in [0, v_L)$, where v_L is defined below, and the buyer's return is normalised to zero. These payoffs can be thought of as being net returns.

Prior to each period both parties are uncertain about the specific task τ_t required, and the potential surplus associated with it. Further, the expected potential surplus in each period is drawn from $v_t \in \{v_L, v_H\}$, where $v_L < v_H$. v_L is the potential surplus at time t with probability p, and v_H is the potential surplus at time t with probability $(1 - p)$. Note, however, that the potential value of v_t is revealed to the parties at the same time as τ_t. As such, there is no uncertainty regarding v_t at the time of renegotiation in period t. Also note that the performance of τ_t only generates surplus in that period. Assumption 3.1 summarises these points.

Assumption 3.1 *At time t, τ_t is revealed. If τ_t is performed by the seller at time t it generates surplus $v_t \in \{v_L, v_H\}$ for the buyer where $v_L < v_H$. v_L occurs with probability p and the surplus equals v_H with probability $(1 - p)$. However, at time t the relevant v_t is known to both parties. The initial default return to the seller is*

$b \in [0, v_L)$.

Note that as $b < v_L$ innovation must occur in every period in order for total available surplus to be maximised. This is summarised in the following remark.

Remark 3.1 *Given Assumption 3.1, adoption of the innovation is efficient in every period.*

Prior to its revelation, τ_1 cannot be contracted upon. After it has been revealed τ_t becomes verifiable and the two parties may write a contract on this variable. On the other hand, the potential surplus v_t is never verifiable, even in period t. As such, a surplus sharing rule is not a permissible contract. This is similar to assumptions elsewhere in the literature. For example, in Bolton and Scharfstein (1990) a firm's profit is unverifiable to the financier preventing the parties from writing an 'enforceable profit-contingent contract' (p. 95). These points are summarised in Assumption 3.2.

Assumption 3.2 *τ_t is not verifiable prior to period t. At time t it may then be contracted upon. v_t is not verifiable at any point in time.*

Remark 3.2 *As a consequence of Assumption 3.2, it is not possible for the two parties to write a contract specifying a surplus sharing arrangement.*

The assumption concerning the ex ante non-verifiability of τ_t and v_t prevents the parties writing a complete contract at the beginning of the game.

It is assumed that the seller must perform the task τ_t, perhaps because of specialisation. Consequently, as in Hart and Moore (1988) and MacLeod and Malcomson (1993a), the buyer and the seller may not vertically integrate to overcome their bargaining problem. This is stated in Assumption 3.3.

Assumption 3.3 *The buyer and the seller may not vertically integrate.*

An important element of the model relates to the parties' inability to provide complete up-front compensation. To simplify the analysis it is assumed that neither party has access to outside sources of finance and wealth is normalised to zero. Although this seems like an extreme assumption, it is not essential that the parties have zero wealth or no borrowing capabilities. All that is important is that the parties access to funds is limited in comparison with the compensation required. Limited ability to borrow funds may arise because the parties could expropriate surplus or manipulate financial reports. Another reason why feasible compensation could be limited is that utility may not be able to be transferred between parties, or there may be limits on such transfers. This would be the case when one of the parties received a payoff that was intrinsic to themselves. At the extreme there could be no transfer between parties.[†] Assumption 3.4 summarises these points.

Assumption 3.4 *The wealth of both parties is normalised to zero, net of access to external finance.*

Assumptions 3.2, 3.3 and 3.4 are important because if the parties could integrate, for example, by the buyer selling stock to the seller or by the creation of a surplus sharing rule, the incentives to delay innovation could be eliminated. Indeed, in his model of specific investments and hold-up, Williamson (1983) used the integration outcome as his first-best benchmark. Likewise, if the buyer could borrow against future earnings, full compensation could be paid to the other party at the outset of the bargaining process, allowing innovation to occur immediately.

After the potential reform τ_t is revealed to the parties at time t, they can decide whether or not to adopt the innovation. Due to the primacy of the default contract, it is assumed both parties must agree to the change. This is summarised in Assumption 3.5.

Assumption 3.5 *Innovation can only occur by mutual consent.*

This is similar to the model of Hart and Moore (1988) where it was assumed that both parties have a switch with 'yes' and 'no' options. For trade to occur in their

[†]Frankel (1998) studied bargaining when both utility is transferrable (so that side payments are allowed) and when it is not (no side payments are allowed).

model both parties were required to have the switch on 'yes'. This is equivalent to the trade rule in the extensive-form game of MacLeod and Malcomson (1993a and 1993b).†

The objective of both of the parties is to maximise their expected surplus. To simplify the analysis, the parties do not discount second period payoffs. The inclusion of discount factors would only serve to scale second period returns.

3.3 The bargaining solution

The division of surplus resulting from renegotiation is composed of two elements.

First, this model adopts the reduced form bargaining solution used by Chiu (1998).† In the game outside options only affect the division of surplus if players can credibly commit to engaging them in the appropriate subgames. If this is not the case the outside options do not provide a credible threat and do not affect the outcome of the game.

As shown in the property rights literature (see Chiu 1998, De Meza and Lockwood 1998) the form of bargaining solution used can significantly alter the outcome of the game. Consequently, it is important that the bargaining solution chosen is appropriate to the applications in mind. Here, the outside option rule is appropriate as the assumption is the outside option (default) can only be enacted if negotiations are abandoned for that period. As a consequence, the seller is unable to adopt the option while continuing to bargain (as would be the case with an inside option). The threat to enact the default option will only be credible if it is binding.

Consider the bargaining solution that applies in the first period if there is innovation in that period or in the second period provided innovation did not occur previously. If, upon renegotiation, the parties agree to adopt a new contract in

†Also see Malcomson's (1997) discussion of fixed price contracts.

†This bargaining solution is, in fact, a reduced form solution based on the alternating-offers bargaining game with outside options of Shaked and Sutton (1984).

preference to the default, they divide the surplus in the following manner:

$$\{\alpha v_t, (1-\alpha)v_t\} \text{ if } b \leq \alpha v_t; \text{ or} \tag{3.1}$$

$$\{b, v_t - b\} \text{ if } b > \alpha v_t. \tag{3.2}$$

where the first element is the return to the seller, the second the return to the buyer and $\alpha \in [0, 1]$.

Temporarily ignoring the outside option, if innovation occurs the parties split the surplus with the seller and buyer receiving α and $(1-\alpha)$ of the total available surplus respectively. This is the solution presented in equation 3.1. In this case α reflects the relative bargaining power of each of the players in the renegotiation process.[†]

As discussed above, when the seller's share of the surplus inside the relationship (αv_t) is less than the outside option, the seller receives a payment equal to her default payoff b. This is the bargaining solution presented in equation 3.2.

In the current model the seller has an outside option b provided by the default contract. In the incomplete contracts literature, ownership of an asset affects the default payoffs of a party. In Chiu (1998) the outside payoffs for the parties are determined by their asset ownership.[†] In this model the adoption (or otherwise) of a potential innovation affects the default payoffs of the parties and their claim on surplus.

Now consider the bargaining outcome in period $t = 2$. As τ_t only generates surplus in period t, if innovation occurred in the first period the period $t = 1$ contract (specifying the performance of τ_1) generates no surplus in the second period. It is

[†]The relative bargaining strength of the players perhaps reflects each party's expectation of making the first offer, as in MacLeod and Malcomson (1993a) and Sutton (1986). Alternatively, it may relate to exogenous rates of time preference (Rubinstein 1982). Another possible interpretation is that α reflects the perceived probability of a irreconcilable exogenous breakdown in bargaining (Binmore et al 1986). It may also reflect a party's position in the market place. (This issue is discussed further in section 3.5.)

[†]Chiu (1998) explored the effect of altering the bargaining solution on Grossman and Harts' (1986) predictions concerning asset ownership. Specifically, Chiu changes the inside options in Grossman and Hart (1986) to outside options. Also see De Meza and Lockwood (1998).

assumed that neither party can be forced to undertake a trade that yields a negative utility. Clearly, the first period innovation contract will provide the buyer with a negative surplus in period $t = 2$ as τ_1 generates no surplus while the contract requires a payment to be made to the seller. In this case the buyer will opt for not to trade. Consequently, despite the $t = 1$ contract, the effective default for the parties is the no-trade payoff. Moreover, as innovation has already occurred, the seller's initial default payoff b no longer applies. As such, after innovation in the first period, the default payoffs in $t = 2$ are zero for both the buyer and the seller.

Following the discussion above, if innovation has previously occurred, the bargaining solution then reduces to:

$$\{\alpha v_t, (1 - \alpha)v_t\} \tag{3.3}$$

if the parties agree to innovate at time $t = 2$.

Second, in addition to the division of surplus specified by the bargaining rule, either party can offer a transfer F_t to the other party paid for out of their share of the surplus. The inclusion of this additional fixed payment allows either party to pay compensation to the other for any future costs (or potential losses) that result from innovation. F_t is an intertemporal transfer that can be considered as separate from the extensive form bargaining game that results in the division of surplus outlined above. In fact, one of the purposes of the model is to explore situations in which a party may refuse to innovate despite the presence of compensation. Again returning to the union-firm workplace negotiation example, F_t could represent redundancy payments or a sign on bonus. As a convention F_t is a payment made by the buyer to the seller. As both parties cannot borrow and have zero wealth, F_t cannot exceed the amount of surplus available to the party in that period. (In the second period the party has access to the surplus they have received from both period $t = 1$ and period $t = 2$. Second period fixed payments can be made by a player using their first period returns. However, this does not turn out to be an issue in this game.) The total payoffs to either party are their bargaining returns net of any transfer payments.

3.4 Delay in bargaining

The objective of each player is to maximise their expected total surplus over the entire game. As this is two period model with symmetric information the game may be solved by backwards induction so as to find the subgame perfect equilibrium (SPE). This section breaks down the analysis of the game into stages. The first stage analyses the second period innovation decision of both parties. The second stage analyses the buyer's first period decision. The next stage assesses the seller's decision to innovate in the first period when $v_1 = v_L$ for various values of b. The final stage analyses the seller's decision to adopt the first period reform when $v_1 = v_H$.

The main objective of this analysis is to assess whether a delay in innovation can exist as part of a SPE.

3.4.1 Second period reform

First, consider the decision to adopt innovation in the second period for both of the parties. Reform will always occur in the second period, regardless of the outcome in the first period. If reform occurred in the first period the default contract is the period $t = 1$ agreement. As noted above, the performance of τ_1 in period $t = 2$ does not generate any surplus for the buyer. The $t = 1$ contract will also require a payment from the buyer to the seller. As a result, the buyer will not trade on the terms of this contract as his return would be negative. The buyer would choose not to trade according to the default contract as he prefers the zero payoff of no trade. Consequently, the effective default return of the seller is also zero, as there will be no trade in the second period with the period $t = 1$ contract. Further, as reform occurred in the first period, the seller will not receive her initial default surplus of b.

Once τ_2 and v_2 are revealed the parties can renegotiate from the default contract. As both parties have a default payoff of zero, if they agree to innovate the division of surplus is $\{\alpha v_2, (1-\alpha)v_2\}$ to the seller and buyer respectively. Clearly, it is in the interests of both parties to agree to innovation in this situation. No fixed payment (F_2) is required to encourage one party or the other to agree to the second period innovation.

Now consider the decision whether or not to innovate in period $t = 2$ when no innovation took place in the first period. Again, once τ_2 and v_2 have been revealed the parties have the opportunity to renegotiate and adopt the innovation. In this case the default payoffs for each of the parties are given by the initial defaults; that is, b and zero for the seller and buyer respectively. (See the description of the bargaining solution in section 3.3.) From Assumption 3.1, $b < v_2 \in \{v_L, v_H\}$. Consequently, the parties can increase total surplus in the second period by adopting the innovation. Given that the second period is the last in the game, there is no strategic advantage to either party from delaying innovation. Further, as innovation increases total surplus, at least one party can be made better off without making the other party worse off. Consequently, both parties will always adopt the second period innovation. (The division of the surplus is given by equation 3.1 or 3.2.)†

In summary, both parties will agree to innovation in the second period, regardless of the outcome in the first period. This is summarised in Result 3.1.

Result 3.1 *Innovation will always occur in period t* $= 2$*, regardless of the outcome in the first period.*

Proof. See Appendix A. □

The following remark relates directly to Result 3.1 and Assumption 3.1.

Remark 3.3 *As innovation always occurs in period t* $= 2$ *total surplus is maximised in the second period.*

†In fact, the buyer will always be made better off by reform in the second period, whereas the seller may receive the same payoff as she would have received had innovation not occurred. To see this note that by definition $b < v_L$. As a result, the two alternative payoffs for the buyer, $v_2 - b$ and $(1 - \alpha)v_2$, are always positive. For the seller, the second period return from innovation is at least as good as her default payoff: if $b < \alpha v_2$, her return is greater with innovation; if $b > \alpha v_2$ her return is the same with innovation as it is without it. Given this indifference we assume that she will agree to reform as it does not make her worse off. Alternatively, we could assume that the buyer undertakes to make a fixed payment $F_2 = \varepsilon$ where ε is arbitrarily small so as to make the seller strictly prefer innovation.

Following from Remark 3.3, if any welfare loss occurs it will occur in the first period.

An important element of Result 3.1 is that in equilibrium neither player requires any compensation (or additional encouragement) to agree to reform, as both players weakly prefer innovation over no innovation. As such, $F_2 = 0$, as summarised in the following remark.

Remark 3.4 *In equilibrium,* $F_2 = 0$.

3.4.2 The buyer's first period decision

Now consider the buyer's decision to innovate in the first period. The buyer will never wish to delay innovation at $t = 1$. The intuition for this result is as follows. The buyer can only do better in the second stage from innovation in period $t = 1$ as the seller loses her default, improving the buyer's claim on future surplus in some cases. The worst the buyer can do in the first period if innovation occurs is to earn a return of zero. This would occur when the additional inducement payment to the seller F_1 was equal to his entire bargaining claim of surplus in the first period. So, if the parties reform at $t = 1$, in the first period the buyer is never worse off than when there is no innovation. Likewise, when there is first period innovation the buyer is never worse off in the second period. It thus appears that the buyer weakly prefers reform in the first period, however, as it turns out the buyer strictly prefers first period innovation. This is because when the buyer is indifferent in period $t = 1$ he will strictly gain from first period innovation in the second period of the game, as summarised by Result 3.2.

Result 3.2 *The buyer never wishes to delay innovation in the first period.*

Proof. See Appendix A. □

The result allows us to focus on the seller's decision to delay. Clearly, as the buyer will always agree to innovation in the first period, it is the seller in this model who may act strategically to delay innovation.

Another important element of Result 3.2 is that the buyer will be willing to forgo his entire claim on first period surplus, via the fixed payment F_1, to induce the seller to accept innovation at $t = 1$. This is restated in the following remark.

Remark 3.5 *In equilibrium, if necessary the buyer is willing to set the fixed payment F_1 equal to his entire bargaining share of v_1.*

3.4.3 The seller's first period decision when $\mathbf{v}_1 = \mathbf{v}_L$

The seller's decision to delay or adopt the innovation depends on the relative payoffs of two alternatives, namely her two period payoff from delaying innovation in the first period (and accepting it in the second period) and her total payoff from accepting innovation at $t = 1$. If she delays innovation in the first period, her total payoff is her default b in the first period plus her claim on second period surplus. (From Result 3.1, innovation will always occur in the second period.) If the seller accepts first period innovation her total expected utility is her first period claim on surplus, plus any fixed payments F_1 from the buyer, as well as her claim on second period surplus given innovation in the first period. In any SPE, the seller will act to maximise her expected utility from both periods.

Consider the seller's decision in period $t = 1$ when $v_1 = v_L$. If $b < \alpha v_L$ the seller's surplus from agreement in the first period is αv_L , not considering, at this stage, any additional payment F_1 from the buyer. Thus, anticipating the outcome the bargaining game in the second period given that innovation has occurred in the first period, the expected total surplus of the seller from both periods is $\alpha v_L + \alpha v_2^e$, where v_2^e is the expected surplus in the second period. That is, $v_2^e = pv_L + (1-p)v_H$. Alternatively, if the seller chooses to delay reform in the first period she will receive a payoff equal to her (default) outside option, b. Again, anticipating her claim on the surplus in the second period, her total expected utility is $b + \alpha v_2^e$.

In this case, it is apparent that the seller will never wish to delay innovation. To see this consider the expected delay payoff minus the expected payoff to the seller when she accepts first period innovation (without any F_1). This relative payoff is

$b - \alpha v_L < 0$. If $v_1 = v_L$ and $b < \alpha v_L$ first period innovation is always in the interests of the seller as she does better with innovation than without it. Further, as reform is in the seller's interests, the buyer does not need to offer any additional payment F_1 to induce the seller to adopt change.

Now consider the case when $\alpha v_L < b < \alpha v_H$. If the seller accepts first period innovation her expected payoff is $b + \alpha v_2^e$ plus any fixed payment F_1 forthcoming. (This is because when $\alpha v_L < b$ the seller's default is binding if innovation takes place.) On the other hand, if the seller delays first period innovation her expected utility is $b + pb + (1-p)\alpha v_H$, where $pb + (1-p)\alpha v_H$ is the expected second period return for the seller. (This is the case as the outside option is only binding if $v_2 = v_L$, which occurs with probability p. If $v_2 = v_H$, which occurs with probability $(1-p)$, the default is not binding and the seller simply receives a share $(1-\alpha)$ of v_H.) The relative payoffs from when the seller delays innovation and when she agrees to it is $p(b - \alpha v_L) > 0$. As the return from delay exceeds the expected return to the seller from immediate innovation, the buyer needs to make a payment F_1 to the seller to make her at least indifferent between the payoff when she delays innovation as compared with when innovation occurs immediately. As the buyer has limited funds, he can only make a payment out of his claim on the first period's surplus. Thus, the largest possible F_1 the buyer can make is $v_L - b$. Thus, delay will only occur when the buyer cannot adequately compensate the seller for the loss she will incur if innovation occurs in the first period (relative to her expected delay payoff). That is,

Buyer's funds < Net gain to seller from delay.

Thus delay will occur if

$$v_L - b < p[b - \alpha v_L] \tag{3.4}$$

or if

$$b > v_L \frac{(1+\alpha p)}{(1+p)}. \tag{3.5}$$

Of course, if $b \leq v_L \frac{(1+\alpha p)}{(1+p)}$, the buyer will be able (and willing) to adequately compensate the seller. If this is the case, the seller will agree to immediate reform.

Clearly, if $b \leq \frac{v_L(1+\alpha p)}{(1+p)}$, the buyer will set $F_1 < v_L - b$, so as to make the seller just indifferent between reform and delay. A larger F_1 would not alter the seller's decision to innovate but would merely act to reduce the buyer's surplus. (The implicit assumption here is that the buyer has all the bargaining power as regards to the compensation payment F_1. Any alternative assumption, for example the assumption that the seller can make a take-it-or-leave-it offer to the buyer, will not affect the incidence of delay. It will merely act to alter the distribution of surplus.)

Now consider when $v_L > b > \alpha v_H$. Remember, by assumption, $b < v_L$. If the seller delays first period innovation her expected surplus is $b + b$. Here, she receives her default in the both periods, as her outside option is binding in the second period bargain. Alternatively, if the seller agrees to innovation in the first period her expected return is $b + \alpha v_2^e$, plus any fixed payment F_1. Her bargaining claim in the first period is b as her outside option is binding. In this case, the seller's delay payoff relative to her innovation payoff, without any fixed payments, is $b - \alpha v_2^e > 0$. The seller requires some compensation for $t = 1$ innovation. Adequate compensation is not possible if $F_1 < b - \alpha v_2^e$. This is the case when

$$v_L - b < b - \alpha v_2^e \tag{3.6}$$

or if

$$b > \frac{1}{2}(v_L + \alpha v_2^e). \tag{3.7}$$

On the other hand, if $b \leq \frac{1}{2}(v_L + \alpha v_2^e)$, the buyer can provide the seller with adequate compensation, and innovation will be immediate.

The discussion above is summarised in the following result.

Result 3.3 *(a) If $v_1 = v_L$, the seller will accept innovation in the first period when: (i) $b < \alpha v_L$; (ii) $\alpha v_L < b < \alpha v_H$ and $b \leq v_L \frac{(1+\alpha p)}{(1+p)}$; and (iii) $v_L < b < \alpha v_H$ and $b \leq \frac{1}{2}(v_L + \alpha v_2^e)$. (b) The seller will delay innovation in the first period when $v_1 = v_L$ if: (i) $\alpha v_L < b < \alpha v_H$ and $b > \frac{v_L(1+\alpha p)}{(1+p)}$; or if (ii) $v_L < b < \alpha v_H$ and $b > \frac{1}{2}(v_L + \alpha v_2^e)$.*

Proof. See Appendix A. ☐

Result 3.3(b) demonstrates that in certain circumstances the seller may act strategically and delay the adoption of a surplus enhancing innovation so as to increase her overall expected payoff. If agreement reduces a player's claim on future surplus they will require some compensation if they are to accept the change. Without sufficient up-front compensation, or a credible commitment to future payments, a party may wish to delay a surplus enhancing innovation. Consequently, at the end of period $t = 1$, even though it may appear that the parties have forgone a potential Pareto reform, they are in fact maximising their own surplus in the multi-period game. Further, where appropriate, a bargain should be considered as a continuing relationship as this significantly alters the analysis.

Following from Remark 3.1, when delay occurs total surplus is not maximised. This is summarised in the following corollary.

Corollary 3.1 *If Result 3.3(b) holds, so that innovation is delayed, total surplus is not maximised.*

Proof. Let W_D denote the total surplus shared between the two parties over the two periods when there was no innovation in period $t = 1$. Similarly, let W_A denote total surplus when there is first period innovation and $\Delta W = W_D - W_A$. As $W_D = b + v_2^e$ and $W_A = v_L + v_2^e$ $\Delta W = b - v_L < 0$. If there is no $t = 1$ innovation - that is, Result 3.3(b) holds - surplus is not maximised. □

Now consider some comparative statics of the model. Define ΔU as the seller's expected payoff over the two periods from delaying agreement minus her expected payoff over the two periods if she accepts innovation in the first period.† Each of the equations below relates to the seller's decision to innovate when she is just indifferent between innovation and delay, that is, when $\Delta U = 0$. Consider first the effect of b when $v_1 = v_L$ and $\alpha v_L < b < \alpha v_H$:

$$\partial \Delta U / \partial b = p + 1 > 0. \tag{3.8}$$

†Specifically, let U_D^S be the seller's ex ante expected utility when she does not agree to the first period innovation. Further, let U_A^S be the seller's ex ante expected utility when she does agree to the period $t = 1$ innovation. From this, $\Delta U = U_D^S - U_A^S$.

An increase in the outside option b increases the incentive for the seller to delay. By accepting innovation, the seller gives up her outside option in the second period - this is a cost of innovation. An increase in b means that the outside option allows the seller to capture more surplus in the second period when $v_2 = v_L$. This means it is less likely that the buyer can provide adequate compensation. Further, an increase in b increases the seller's default payoff in the first period, decreasing the cost of forgoing that period's surplus from reform (in the form of payment F_1).

Further, note that as delay becomes more likely as b increases, the loss in surplus decreases. This suggests that the innovations that will be stalled are those that provide only small increases in surplus. Conversely, the model suggests that significant reforms are more likely to be accepted immediately as they are more likely to generate enough surplus to make compensation possible.

Next, consider the effect of a change in α:

$$\partial \Delta U / \partial \alpha = -p v_L < 0. \tag{3.9}$$

An increase in α decreases the incentive for the seller to delay first period innovation. α represents the seller's claim on surplus in any period when the default is irrelevant. Thus a higher α indicates that the seller will get a greater share of the surplus from any innovation, disregarding the default. As well as meaning that the seller is more likely to be the beneficiary of any innovation, given that b will bind only when $v_2 = v_L$ an increase in α reduces the cost of forgoing this default, decreasing the compensation needed to induce innovation.

Both b and α represent different forms of bargaining strength. b represents a historical default or contractual right that acts as a minimum the seller must receive. On the other hand, α could represent current bargaining strength in the renegotiation process. α represents the seller's negotiation skills or patience relative to those of the buyer, regardless of any historical options. Although there may be some correlation between b and α, this is not necessarily the case. For example, a union may have as a default position rights and conditions that were obtained in a different bargaining environment. In negotiations, the union can then refuse any change that fails to provide its members with at least the same level of surplus as this default. However, unions may differ in their ability to bargain with an employer in the absence of a default.

Next consider the effect of v_L and p when $v_1 = v_L$ and $\alpha v_L < b < \alpha v_H$:

$$\partial \Delta U / \partial v_L = -(1 + \alpha p) < 0; \tag{3.10}$$

and

$$\partial \Delta U / \partial p = b - \alpha v_L > 0. \tag{3.11}$$

An increase in v_L decreases the incentive for the seller to delay first period innovation. An increase in v_L increases the probability that the buyer can afford adequate compensation, in part because an increase in v_L decreases the potential losses to the seller in the second period from giving up her default and also because it increases the potential first period payment F_1 the buyer can make. An increase in p increases the incentive to delay because it increases the chance that $v_2 = v_L$, in which case b will bind, increasing the probability that the seller is giving up a real claim on second period surplus from accepting $t = 1$ innovation.

Similarly, the comparative statics when $v_1 = v_L$ and $v_H > b > \alpha v_L$ are as follows:

$$\partial \Delta U / \partial b = 2 > 0; \tag{3.12}$$

$$\partial \Delta U / \partial \alpha = -v_2^e < 0; \tag{3.13}$$

$$\partial \Delta U / \partial v_L = -(1 + \alpha p) < 0; \tag{3.14}$$

$$\partial \Delta U / \partial p = -\alpha v_L + \alpha v_H > 0; \tag{3.15}$$

and

$$\partial \Delta U / \partial v_H = -\alpha(1 - p) < 0. \tag{3.16}$$

The only additional variable considered here is v_H. An increase in v_H decreases the expected loss from innovation at $t = 1$ in the second period as it increases the seller's bargaining claim when $v_2 = v_H$.

3.4.4 The seller's first period decision when $\mathbf{v}_1 = \mathbf{v}_H$

Now consider the case when $v_1 = v_H$. The seller will go through the same decision process as before. Specifically, she will compare the two period payoff if she delays in the first period with the payoff she would expect to receive when innovation occurs at $t = 1$. Delay will occur when first period compensation is insufficient to cover expected future losses. Result 3.4 summarises the seller's decision when $v_1 = v_H$.

Result 3.4 *(a) If $v_1 = v_H$, the seller never wishes to delay when: (i) $b < \alpha v_L$; (ii) $b \in (\alpha v_L, \alpha v_H)$ and $b \leq (\alpha p v_L + v_H)/(1+p)$; and if $b \in (\alpha v_H, v_L)$ and $b \leq \frac{1}{2}(v_H + \alpha v_2^e)$. (b) If $v_1 = v_H$, the seller will delay first period innovation if: (i) $b \in (\alpha v_L, \alpha v_H)$ and $b > (\alpha p v_L + v_H)/(1+p)$; (ii) or if $b \in (\alpha v_H, v_L)$ and $b > v_H \frac{(1+\alpha(1-p))}{2} + \frac{\alpha p}{2} v_L = \frac{1}{2}(v_H + \alpha v_2^e)$.*

Proof. See Appendix A. □

As noted above, if innovation is not adopted immediately total surplus is not maximised.

Corollary 3.2 *If Result 3.4(b) holds total surplus is not maximised.*

Proof. Following the proof of Corollary 1, $W_D = b + v_2^e$ and $W_A = v_H + v_2^e$. As such, $\Delta W = b - v_H < 0$. Consequently, delay in innovation reduces total surplus. □

Another important element of this result is that the range of parameter values in which delay occurs in equilibrium when $v_1 = v_H$ is smaller than when $v_1 = v_L$. If $b \in (\alpha v_L, \alpha v_H)$ and $v_1 = v_L$, delay will only occur if $b > \frac{v_L(1+\alpha p)}{(1+p)}$. In comparison, if $b \in (\alpha v_L, \alpha v_H)$ and $v_1 = v_H$, delay requires that $b > (\alpha p v_L + v_H)/(1+p)$. Similarly, if $b \in (\alpha v_H, v_L)$, delay requires that $b > \frac{1}{2}(v_L + \alpha v_2^e)$ if $v_1 = v_L$, whereas if $v_1 = v_H$, for delay to be part of a SPE it needs to be the case that $b > \frac{1}{2}(v_H + \alpha v_2^e)$.

This is not surprising. Delay occurs when the buyer is unable to provide adequate compensation to the seller for her loss in future surplus, or her potential claim on future surplus. When $v_1 = v_H$, the buyer has more surplus with which to make compensation payments.

The comparative statics of the seller's first period when $v_1 = v_H$ and $b \in (\alpha v_L, \alpha v_H)$ are:

$$\partial\Delta U/\partial b = (1+p) > 0; \tag{3.17}$$

$$\partial\Delta U/\partial \alpha = -pv_L < 0; \tag{3.18}$$

$$\partial\Delta U/\partial v_L = -\alpha p < 0; \tag{3.19}$$

$$\partial\Delta U/\partial p = b - \alpha v_L > 0; \tag{3.20}$$

and

$$\partial\Delta U/\partial v_H = -1 < 0 \tag{3.21}$$

The equations below show the comparative statics relating to the seller's decision to delay innovation in the first period when $v_1 = v_H$ and $b \in (\alpha v_H, v_L)$:

$$\partial\Delta U/\partial b = 2 > 0 \tag{3.22}$$

$$\partial\Delta U/\partial \alpha = -v_2^e < 0 \tag{3.23}$$

$$\partial\Delta U/\partial v_L = -\alpha p < 0 \tag{3.24}$$

$$\partial\Delta U/\partial p = -\alpha v_L + \alpha v_H > 0 \tag{3.25}$$

$$\partial\Delta U/\partial v_H = -1 - \alpha(1-p) < 0 \tag{3.26}$$

The interpretation of the comparative statics is broadly the same as when $v_1 = v_L$. An increase in b increases the incentive for the seller to delay innovation in the first period. Conversely, an increase in α decreases the seller's incentive to delay. An increase in v_L decreases the incentive to delay, whereas an increase in p increases the incentive for the seller. An increase in v_H decreases the incentive for the seller to delay, however, in this case as $v_1 = v_H$, an increase in v_H makes it more likely that adequate compensation is feasible.

3.5 Drastic innovation and bargaining power

Some reforms or innovations dramatically alter a party's potential bargaining power. For example, the removal of a closed shop could reduce a union's ability to exact surplus. Realising that such a reform will affect its future negotiating potency, a union would require additional concessions if it were to be induced to accept such a reform. More generally, any innovation that shifts a party (the buyer) from a specific to a general relationship will drastically reduce the other party's bargaining power.[†] Another example would be a reform that eliminates the need for the special skills of a particular agent in the production process so that other (outside) parties can compete for supply. As their skill or input is no longer essential, innovation causes the agent to lose their leverage over the other bargaining agent. To distinguish clearly the two different potential effects of innovation, denote an innovation that reduces the seller's contemporaneous bargaining power as a 'drastic' innovation.

To examine delays in bargaining with drastic innovation consider the following alterations to the basic model. First, suppose the seller's initial default is zero ($b = 0$). In the first bargaining period, if the agreement occurs the division of surplus is $\{\alpha v_1, (1-\alpha)v_1\}$ to the seller and buyer respectively. If not, each player receives a payoff of zero (their default payoff). In the second bargaining period assume the bargaining rule is altered such that if innovation has occurred at time $t = 1$ all of the surplus accrues to the buyer; that is, the division is $\{0, v_1\}$.[†] Clearly, innovation eliminates any claim that the seller might have on surplus in future periods. If, on the other hand, no innovation took place in the first period, the division of surplus is $\{\alpha v_t, (1-\alpha)v_t\}$ for the buyer and seller respectively, as given

[†]See Shaked and Sutton (1984).

[†]An alternative model might not have reform reduce α completely, but rather have innovation reduce α by a fraction between zero and one.

by equation 3.1.

As discussed previously, innovation will occur in the last period regardless of the outcome in the first period. Thus, if agreement occurred in the first period, the seller's expected return is zero (regardless of the value of v_2^e). If reform did not occur, the period $t = 2$ expected return for the seller is $\alpha v_2^e = \alpha p v_L + \alpha(1-p)v_H$.

In the first period, when deciding whether or not to agree to immediate innovation, the seller will take into account the potential loss in the second period. Delay will occur when

$$F_1 + \alpha v_1 < \alpha p v_L + \alpha(1-p)v_H. \tag{3.27}$$

As the buyer never wishes to delay innovation, he is willing to make the fixed payment equal to the highest feasible payment; that is, he is willing to set $F_1 = (1-\alpha)v_1$. As such, delay will occur when

$$\alpha v_1 + (1-\alpha)v_1 = v_1 < \alpha p v_L + \alpha(1-p)v_H. \tag{3.28}$$

From this, when $v_1 = v_L$, the seller will delay innovation in period $t = 1$ when

$$v_L < \frac{\alpha(1-p)v_H}{(1-\alpha p)}. \tag{3.29}$$

If $v_1 = v_H$, delay never occurs in equilibrium because the seller can always receive adequate compensation for her loss in future bargaining power.

Unlike the basic model, the incentive to delay is increasing in α

$$\partial \Delta U / \partial \alpha = v_2^e > 0. \tag{3.30}$$

This, at first appearance, is a seemingly different result to prediction of the previous section. In the basic model the default b represented historical bargaining strength, and a seller was more likely to delay innovation in the first period, at the margin, given an increase in b. Innovation, however, caused the seller to lose this default. In the model in this section, innovation diminishes the bargaining power of one of the parties. As such, what the seller forgoes by accepting innovation in the first period is increasing in α. In this manner, the results relating to these two variables are consistent.

3.6 Predictions of the model

The two different specifications allow for different predictions, however. The first two predictions below relate to the basic model. The third relates to the model of drastic innovation. The last contrasts the two models.

Prediction 3.1 *A party with a strong historical position (b) is more likely to delay innovation.*

In the basic model the default only increases the seller's expected claim on future surplus if it is to be binding. At the margin, this is more likely the higher the default. Prediction 3.1 suggests, for example, that a union that has won generous conditions for its members over time, reflecting its historical position of strength, is less likely to accept innovation.

Prediction 3.2 *A party with a strong claim on current surplus (bargaining power α) is more likely to accept innovation.*

An example of this would be a worker with specific skills who is required by the firm for the new technique or process to be used. Conversely, an agent with relatively weak claim on current surplus is more likely to delay innovation. This is the opposite prediction of most of the asymmetric information bargaining models in which it is the strong agent who endures delay in order to signal their bargaining strength to the other party.

Prediction 3.3 *The stronger the initial bargaining strength of a party facing a drastic innovation (α goes to zero), the more likely they are to reject innovation.*

Further to this, a party that loses more of its bargaining strength is more likely to oppose innovation. For example, a craft based union is more likely to oppose innovation than a union that represents a broader range of occupations and interests. This is the case because innovation (new technology) is more likely to reduce a craft based union's bargaining power, whereas a broader union may be better placed to capture any increase in surplus. This prediction accords with the conclusion of Dowrick and Spencer (1994). They argued that union opposition to innovation tends to occur when union preferences are weighted in favour of jobs and labour demand is inelastic. Given the assumption that the elastic of demand is lower at the industry level than at the enterprise level, they concluded that industry or craft based unions are more likely to oppose technical change than enterprise unions. This logic may well have been one of the motivations behind the shift in the late 1980s by both the Australian Federal Labor Government and the Australian Council of Trade Unions to amalgamate smaller, craft based unions to form larger more broadly represented unions.[†] Similar arguments have been made comparing resistance to innovation from decentralised unions in the UK compared with the corporatist unions in the then West Germany (see the discussion in Willman 1986, p. 33).

Prediction 3.4 *A party with a strong historical default is more likely to delay when future surplus is expected to be low (basic model). A party facing drastic innovation is more likely to delay when future surplus is expected to be high (drastic innovation model).*

As a concrete example, consider a union bargaining with a firm. If the union has a high default position it is more likely to reject innovation when the industry is in decline, as the default is more likely to influence the distribution of surplus in the future.[†] Future surplus may be low because of the impending removal of reg-

[†]Both the *Industrial Relations Act 1988* and the *Industrial Relations Legislation Amendment Act 1990* attempted to increase the minimum size of a union from 100 to 1000, then to 10 000. Following a ruling by the International Labour Organisation this number was again reduced to 100 by the *Reform Act 1993*. Further, evidence from the Australian Workplace Industrial Relations Survey 1995 showed that, according to union delegates of the main union at the workplace, 58 per cent of these unions had been involved in amalgamations. This is 36 per cent of all unionised workplace. Further, 30 per cent said that employees at different workplaces had become members of the same union.

[†]This discussion does not consider the possibility that the default exceeds the potential surplus from innovation in the future.

ulations or the introduction of new competitors, as well as an industry in decline. On the other hand, the drastic innovation model suggests that employees in a declining industry would accept innovation immediately. Instead, a union would delay innovation when expected future surplus is higher than today's potential surplus. This would be the case in an industry that expected a growth in demand (ignoring possible entry of other suppliers).

3.7 Comparison with the literature

The insight of this model is that a bargaining party may act strategically, reducing overall surplus. If the decision to innovation is thought of as an investment, the predictions of the model look similar to the finding of some incomplete contracts models. That is, the parties will take into account the ex post consequences (during renegotiation) of their ex ante actions (investment). In Grout's (1984) paper, for example, the firm takes into account the ex post bargaining game with the union, and adjusts its ex ante investment accordingly. Similarly, in Grossman and Hart (1986) the parties invest taking account of any potential hold-up in the renegotiation stage that occurs after the parties have invested. In the model presented here, the second period bargaining game is similar to the ex post bargaining stage in the incomplete contract model. As in Grossman and Hart (1986), the ex post bargaining game (the second period investment) is efficient. However, ex ante investment or first period innovation may not be efficient because one of the parties may act strategically to position themselves better in ex post (second period) renegotiation.

As noted above, however, the model here involves a cooperative investment. Several papers have discussed institutions that are designed to ensure efficient cooperative investment. Malcomson and MacLeod (1993a) studied contracts designed to encourage efficient ex ante investments. They demonstrated that designing the initial contract so as to give one party all of the bargaining power during renegotiation encourages efficient ex ante investments. As this party becomes the residual claimant they receive the full return from any investment, giving them first-best incentives to invest. Alternatively, if a contract can be written that will not be renegotiated, for example a fixed-price contract, hold-up is avoided. Neither of these solutions is applicable here as renegotiation is essential to implement the new innovation in order to generate the surplus. Further, the parties cannot commit to a future price, as the second period price reflects the bargaining process as summarised by equations 3.1, 3.2 and 3.3.† Che and Haush (1999) found that where they are unable to commit not to renegotiate, parties cannot do any better than to have no contract at all and accept the inefficiency effects caused by ex post renegotiation. Given the structure of the model here the parties will wish to renegotiate, and any commitment otherwise would not be credible.

Frankel (1998) examined a related model. In his model both parties had the opportunity to search for new options that could enhance the bargaining surplus. However, some search activities enhance a player's own payoff while others increase the joint surplus available (as in a cooperative investment). Under the first assumption the two parties can make side payments. In this case there is underinvestment in search activity as a party will not receive the entire return generated by their investment. This result is similar to the underinvestment result of the hold-up literature. When side payments are not allowed (that is, utility is not transferrable and no compensation can be paid) each party strategically searched for ideas that are advantageous to them, rather than ideas that generate surplus per se. Given this, there may be either under or over investment in this kind of selfish search activity.

Hart and Moore (1994) studied optimal debt contracts between a wealthy creditor and a debtor who possessed some inalienable human capital without which the project could not go ahead. In their model ex ante inefficiency arises, in the sense that projects with a certain positive net return are not financed, because of incomplete contracts (the debtor cannot commit not to threaten to withdraw her capital which causes renegotiation) and wealth constraints (profitable projects would always proceed if the debtor had sufficient wealth). These results are similar to those of this

†In another paper, Che and Chung (1999) found that a reliance-damages contract can ensure efficient cooperative investments.

paper. Some of the comparative statics also parallel the results here. For instance, a project is more likely to be financed if the physical assets are more durable. As the investor receives the physical assets in the event of default, this improves her renegotiation position, reducing the hold-up problem. This is similar to the seller in the model presented here having a higher α providing her with a higher claim on future surplus. Similarly, when returns from the project are front-loaded the investor's bargaining position is enhanced as the liquidation values of the project are high at the time when the investor requires the additional coverage. This additional security means that a project is also more likely to proceed. However, in Hart and Moore the bargaining power at the renegotiation stage is determined by the characteristics of the project (maturity, the durability of the physical assets involved) whereas here the bargaining power of the parties is determined by previous bargaining outcomes (specific investments). Neher (1999) studied a related venture-capital debt financing model. In his model, in order to overcome the hold-up problem the parties finance the project through a sequence of payments. By financing the project in stages, the debtor has less incentive to renege. Further, as the project matures, Neher assumed that over time the alienable element of the project, manifest in physical assets for example, increases, providing a better default position during renegotiation for the creditor in the event of a default. This model potentially relates to the incentive to institute reform as a sequence of small changes over time. This issue is briefly discussed below.

Dowrick and Spencer (1994) examined when a union could expect to gain or lose from the introduction of a labour saving technology. From this they predicted under what conditions a union would oppose innovation and under what conditions they would embrace change.† As in the model presented here, Dowrick and Spencer (1994) predicted that if the interests of the two bargaining parties are aligned regarding reform, the innovation will occur without delay. However, the model presented here has multiple bargaining periods whereas in Dowrick and Spencer there is one potential innovation and one production period. In addition, they did not consider

†Also see Ulph and Ulph (1988).

the possibility of the firm compensating the union for the losses incurred. On the other side of the coin, much of the theoretical bargaining literature has assumed that bargaining is immediate because compensation is always possible if agreement involves an increase in total surplus. This paper goes some way to bridging the gap between the two streams of literature. In the model presented here delay can still occur in equilibrium because of the following three features of the model: the addition of a second bargaining period; the inability of the parties to write fully contingent contracts; and wealth constraints that may prevent adequate compensation.

Finally, it is worth contrasting this model to the work of Dixit and Pindyck (1994). In their framework there is uncertainty about the future returns of an irreversible investment. The firm has the opportunity, however, to delay investment in order to gather better, although not necessarily perfect, information. Consequently, delay of the investment has an option value. The firm will then weigh the cost of delay against the benefits of waiting for new information.

The model in this paper is similar in the sense that innovation is irreversible; once the seller has agreed to change the default contract they cannot unilaterally decide to reinstate it. There are several crucial differences, however. First, delay occurs for different reasons in the models. In Dixit and Pindycks' model it is uncertainty that causes a firm to delay investment.[†] On the contrary, in the model presented here it is incomplete contracts and wealth constraints that cause strategic delay; if adequate compensation can be provided up-front for future losses innovation will be immediate. Second, delay in the model here reduces total welfare with certainty. This is not the case in Dixit and Pindyck where delay, although possibly involving some cost, can increase total surplus by improving the firm's investment decision.

[†]In fact, Dixit and Pindyck noted that the option value - and hence the incentive to delay - is not affected if a firm can hedge this risk on the forward or futures market (p. 11). This suggests that investment is delayed not because of a lack of insurance (an incomplete market) but because waiting improves the information available: it is the extra information that is important, not attitudes towards risk.

3.8 Extensions

The basic model captured the on-going relationship between the parties in a two-period model. This section extends the model to three periods and to an infinite horizon. Second, it discusses how delays may arise when commitment is not possible. Third, it contrasts the incentives to delay with general and specific investments (innovation). Last, the section briefly discusses partial reform when there are many potential innovations that can be implemented in any given period.

3.8.1 Three period model

With the two period model the seller's decision is whether to wait and accept innovation immediately or whether to accept it in the next (and final) period. In reality, as bargaining is typically an on-going process, both parties must decide in which period they wish to accept innovation. The timing of reform then becomes important. One way of adapting the basic model is to consider the second period payoffs as reflecting the outcome that will occur when both parties play optimal strategies for the remainder of the game, however long that maybe. Alternatively, this section considers a three period model.

To simplify the analysis consider a model in which the potential surplus in each period is certain from the beginning of the game. Denote the potential surplus in each period as v_1, v_2, and v_3. Further, adopt the bargaining rule and default option assumptions of the basic model. First, consider the second two periods of the game. At this junction, if innovation has not occurred in the first period, the parties must decide whether they wish innovation to occur in that period or in the final period. Once again, it is never in the interests of the buyer to delay innovation and he will be willing to forgo his entire share of surplus in that period ($t = 2$) in order to induce the seller to innovate. The seller again compares the two period payoff when there is no innovation in the first ($t = 2$) period with the two period payoff when she agrees to immediate innovation. If $b > \alpha v_2$ and $b > \alpha v_3$, the delay payoff for the seller is $b + b$. If the seller agrees to innovation at $t = 2$ her payoff would be $b + F_1 + \alpha v_3$. Letting $F_1 = 0$, $\Delta U = b - \alpha v_3 > 0$, thus the seller requires compensation in order to be induced to innovate. Delay will occur when sufficient compensation is not possible, thus delay will occur when $b > \frac{1}{2}(v_2 + \alpha v_3)$. (This model has the same properties as the basic model. That is, the incentive to delay is increasing in b, and decreasing in v_2 , v_3 and α.)

Now consider an additional period that occurs before the two periods discussed above, and again consider the case when $b > \alpha v_i$, for $i = 1, 2, 3$. At time $t = 1$, the outcome of the subsequent periods are already anticipated by the two parties: both parties know the choice of the seller at $t = 2$ if innovation does not occur in the first period. Thus, in order to induce the seller to accept innovation in the first period, the buyer need only provide the seller with a payoff equal to her payoff in the two period game plus her first period default b. If the seller agrees to first period reform she receives $b + F_1 + \alpha v_2 + \alpha v_3$. If in the two period game the seller would delay, in order to induce immediate innovation the buyer must ensure that $\Delta U = b + b + b - [b + F_1 + \alpha v_2 + \alpha v_3] \leq 0$. As a result, the seller will delay first period innovation if $b > \frac{1}{3}[v_1 + \alpha v_2 + \alpha v_3]$.

If the seller would agree to immediate innovation in the two period game, in order to induce $t = 1$ agreement in the three period game the buyer needs to ensure that $\Delta U = b + b + F_2 + \alpha v_3 - [b + F_1 + \alpha v_2 + \alpha v_3] \leq 0$. F_2 is set so that $b + b - [b + F_2 + \alpha v_3] = 0$ or that $F_2 = (b - \alpha v_3)$. Substituting this into the above equation lets $\Delta U = b + b + (b - \alpha v_3) + \alpha v_3 - [b + F_1 + \alpha v_2 + \alpha v_3]$. This is positive when $F_1 = 0$, implying that first period compensation is needed to facilitate the seller to innovate immediately. Delay will occur when the available first period compensation is not adequate, or when $b > \frac{1}{3}[v_1 + \alpha v_2 + \alpha v_3]$.

In the three period model, the seller can decide to delay innovation either one or two periods. Although total surplus is maximised by immediate innovation, the seller could opt to innovate in any of the periods. In fact, the addition of another period does not make immediate agreement any more or less likely a priori. In the two period model immediate agreement was reached provided $b_2 \leq \frac{1}{2}(v_2 + \alpha v_3)$, relabelling the periods to correspond to the last two periods in the three-period game. On the other hand, immediate agreement is only possible in the three period model when $b_3 \leq \frac{1}{3}[v_1 + \alpha v_2 + \alpha v_3]$. It turns out that either b_2 or b_3 could be larger. If $v_1 > \frac{(3-2\alpha)}{2}[v_2 + \alpha v_3]$, the addition of the extra period decreases the chance of delay by increasing the minimum level of b for which it is optimal for the seller to delay. Conversely, if $v_1 < \frac{(3-2\alpha)}{2}[v_2 + \alpha v_3]$ the addition of the extra period increases the chance of delay as the minimum level of b necessary for the seller to delay in equilibrium is lower than with a game consisting of only the last two periods.

Similarly, when lost surplus is considered as a proportion of total surplus, the welfare effects of the additional period is ambiguous. For example, if there are two periods of delay, in the extended model the proportional welfare loss is $[(v_1 - b) + (v_2 - b)]/(v_1 + v_2 + v_3)$. This may be greater than or less than the proportional welfare loss of a one period delay in the two period model of $(v_2 - b)/(v_2 + v_3)$. In some cases, however, the addition of a period unambiguously improves welfare. This is the case when the seller would have delayed agreement in the two period model but is willing to innovate immediately in the three period model. These results concord with the findings of Fudenberg and Tirole (1983) who found that, in a bargaining model with asymmetric information, the addition of extra bargaining periods had an ambiguous effect on welfare.

3.8.2 Infinite horizon

This analysis could be extended to an infinite horizon model. Consider a model where potential innovation produces a surplus of v in every period. As before, the seller has a default of b that is inconsistent with innovation, the relative bargaining strength of the parties is reflected in the parameter α and the default is binding in the bargaining process for the seller. In addition, assume the seller has a discount factor of $\delta \in (0, 1)$.

Given the stationarity of the model, the optimal action in any one period will also be optimal in every period. Thus, if the seller does not wish to innovate, she will not wish to innovate in any period. In that case, the discounted value of surplus to the seller of delay is:

$$b + \delta b + \delta^2 b + \delta^3 b + \ldots = \frac{b}{(1-\delta)}. \tag{3.31}$$

On the other hand, the value to the seller from immediate innovation is:

$$b + F_1 + \delta \alpha v + \delta^2 \alpha v + \delta^3 \alpha v + \ldots = b + F_1 + \frac{\delta}{(1-\delta)} \alpha v. \tag{3.32}$$

As before, the buyer does not wish to delay innovation.[†] The maximum innovation payoff for the seller is:

$$v + \frac{\delta}{(1-\delta)} \alpha v. \tag{3.33}$$

Delay will occur when:

$$\frac{b}{(1-\delta)} > v + \frac{\delta}{(1-\delta)} \alpha v; \tag{3.34}$$

or when

$$b > (1 - \delta + \alpha\delta) v. \tag{3.35}$$

Unlike models with one-sided asymmetric information, the seller is willing to endure a prolonged delay in bargaining. The comparative statics for the delay decision are as follows:

$$\partial \Delta U / \partial b = \frac{1}{1-\delta} > 0; \tag{3.36}$$

$$\partial \Delta U / \partial v = -\frac{(1 - \delta + \alpha\delta)}{1-\delta} < 0; \tag{3.37}$$

$$\partial \Delta U / \partial \alpha = -\frac{\delta v}{1-\delta} < 0; \tag{3.38}$$

and

$$\partial \Delta U / \partial \delta = \frac{(b - \alpha v)}{(1-\delta)^2} > 0. \tag{3.39}$$

The new variable here is the discount factor. Equation 3.39 shows that delay is more likely the more patient the seller is.

[†]Note that in this section it is implicitly assumed that payoffs cannot be carried over between periods.

The results of this model are similar to infinite horizon games of tacit collusion,[†] however, the emphasis here is reversed. Tacit collusion models examine whether the threat of low future payoffs (punishment) is sufficient to sustain collusion without cheating in the immediate term. On the other hand, in the model of delay the emphasis is on whether the immediate reward (compensation) is sufficient to induce the seller to accept a lower payoff in the future. The impact of the discount factor is also reversed. In the standard models of tacit collusion a higher discount factor increases the incentive for the firm to cooperate. Here, a higher discount factor means that the seller is more patient and requires more compensation if they are to agree to innovation.

Thus far in this section it has been assumed that payoffs cannot be carried over between periods. As wealth constraints are an important element to the reason for delay, it could be expected that the buyer could accumulate savings over several periods so as to have sufficient funds to compensate the seller adequately. Assume that the buyer receives a small return r from each period of trading that occurs according to the old default contract, where r is never binding and is sufficiently small so as to ensure that innovation is still optimal. Let the accumulated savings of the buyer be represented by S. In this case, delay will occur when:

$$v + S + \frac{\delta}{(1-\delta)}\alpha v \leq \frac{b}{(1-\delta)} \tag{3.40}$$

so that the buyer will wish to accumulate savings $\widehat{S} = [b - v(1 - \delta + \alpha\delta)]/(1-\delta)$ in order to induce innovation. Delay in innovation will be longer the smaller is r and the larger is $\widehat{S}$.

3.8.3 Inability to commit not to renegotiate

Thus far we have assumed that the two parties have been unable to write a fully contingent contract in period $t = 1$ covering the events of period $t = 2$. This incompleteness arises because τ_t only becomes verifiable at time t. Consequently,

[†]See Tirole (1988) Chapter 6.

prior to that point in time it is not possible to write a contract specifying the performance of τ_2. As such, the parties write only a one period contract (covering the performance of τ_1, the bargaining solution and any fixed payment F_1 to be made, if necessary) understanding that the contract will be renegotiated before trade in period $t = 2$. Further, it was assumed that τ_t only generated surplus in period t.

As noted above, contracts will effectively be incomplete where parties cannot commit to not renegotiate. This section briefly examines the incentive for delay when the innovation is contractible from the start of the game but the parties can always opt to renegotiate.† In fact, as it turns out, the same results concerning innovation and delay may result if parties cannot commit to not renegotiate in future periods.

Consider the following modifications. First, allow τ_t to, if adopted, generate surplus in every period after it has been adopted. However, prior to each period, there is uncertainty regarding the potential surplus. Specifically, let $v_t \in \{v_L, v_H\}$ where $v_L < v_H$, and let $v_t = v_L$ with probability p, and $v_t = v_H$ with probability $(1-p)$ as before. All of the other assumptions apply. In particular, the bargaining rule remains the same as in the basic model. However, in this section assume that the parties cannot commit not to renegotiate the existing contract. That is, in period $t = 2$ either party can trigger renegotiation if it is in their interests.

Assume that once a party has triggered renegotiation each player will receive their default payoff, unless they agree to a new contract. As before, any new contract needs to be adopted by mutual consent. As such, if innovation has not occurred, the default payoffs of the seller and buyer are b and zero respectively (Assumption 3.1). As above, the no reform bargaining rule is given by equation 3.1 or 3.2. If innovation has previously occurred the seller is assumed to have lost her initial default, and the relevant defaults for both parties are zero: equation 3.3 gives the bargaining rule if

†The assumption that the parties are unable to commit to not renegotiate relates directly to the hold-up model of Grout (1984). A similar assumption is also made by Hart and Moore (1994) in which the entrepreneur can always unilaterally opt to renegotiate the contract because there is no mechanism by which they can be sanctioned for doing so. It also relates to the bargaining models in which commitment to a future strategy is not possible, for example Sobel and Takahashi (1983).

innovation occurred in period $t = 1$.

First, consider the case in which innovation did not occur in period $t = 1$. In the second period innovation will occur with probability equal to one, and the division of surplus will be given by equations 3.1 and 3.2. At this juncture there is no possible strategic benefit from delay, so no compensation (F_2) is ever required. In this case the total payoff to the seller will be b (from the first period) plus her second period payoff (given by the bargaining rule). The buyer will simply receive his share of the second period return.

Each party will compare these payoffs (the expected return from delaying innovation) with their expected payoff if reform occurs immediately. As it turns out, renegotiation will always occur in the second period if innovation occurred in period $t = 1$, despite the fact that the default contract would generate surplus in period $t = 2$. Renegotiation will always occur because the parties cannot commit to not renegotiate the existing contract and it is always in the interests of one party to renegotiate the contract. Further, only one of the parties is needed to trigger renegotiation. As such, both parties will ex ante expect renegotiation will occur at period $t = 2$.

Consider the case when the first period's return to the seller was b (for example, $v_1 = v_L$ and $b \in (\alpha v_L, \alpha v_H)$ and $b > v_L(1 + \alpha p)/(1 + p)$.) If the second period's potential surplus turns out to be v_L the buyer will initiate renegotiations.† Once renegotiations have been restarted the buyer is in a better bargaining position because the seller no longer has her default, so the surplus split will be $\{\alpha v_L, (1-\alpha)v_L\}$. Likewise, if $v_2 = v_H$ and $b < \alpha v_H$ the seller would restart renegotiations, the resulting division would be $\{\alpha v_H, (1 - \alpha)v_H\}$. Further, if innovation occurred in the first period when $v_1 = v_H$ and $v_2 = v_L$, it might be necessary for the initial contract to be renegotiated as the contract could give the buyer a negative payoff. In such a case, no trade would be preferable to the buyer, so he would initiate renegotiation.

The upshot of the inability to commit to not renegotiate is that the division

†The only case in which the contract will not be renegotiated at time $t = 2$ is when $v_1 = v_L$, $b < \alpha v_L$ and $v_2 = v_L$. In this case there is never any incentive to delay innovation.

of surplus between the parties over the two periods will be identical to the basic model presented in section 3.4. As such, the seller has the same incentives to delay innovation in period $t = 1$.

This inability to commit to not renegotiate is similar to an 'at-will' contract although in this model both parties have equal power to restart bargaining.† If the model was to be altered to incorporate a traditional 'at-will' bargaining rule, the seller would have a similar incentive to delay innovation, and this incentive may be even greater than in the model presented here.

3.8.4 General and specific investment

Thus far we have assumed a bilateral relationship. In that sense the innovation has been specific to the parties. In this section we consider the possibility of delay with general innovations (investments).

A general investment provides an expected rate of return that is the same regardless of the trading partner. On the other hand, a specific investment generates a return if trade occurs with a specific party, but generates no return if trade takes places with any other trading party. A partially specific investment generates a higher return with the specific trading partner than with other potential trading partners.†

Clearly, if a buyer can immediately substitute another seller from n potential sellers who are identical to the original trading partner, the buyer has all the bargaining power, as in Bertrand competition with a homogenous product. As a result, he will receive all of the surplus generated from innovation and the seller will not receive a payoff above her reservation utility in any period.† In such a situation the

†In an 'at will' contract there is typically an asymmetry in that if the buyer alters the terms of a contract, provided the seller continues to supply, it is deemed that she has agreed to the changes. On the other hand, if a seller suggests a new trading arrangement the old contract remains in place unless the buyer explicitly agrees to the new offer (see Malcomson 1997). As a result of this asymmetry, the buyer is assumed to be able to keep the seller at their reservation utility.

†For more details, see MacLeod and Malcomson (1993b) and Malcomson (1997).

†See Shaked and Sutton (1984). In their model when the buyer can costlessly bargain with a large number of sellers, the distribution of surplus is the same as the outcome of a competitive market.

seller has no bargaining power to hold-up innovation and there will be no delay. For example, again allow the seller to have a default of b. However, now assume that there are also n other potential sellers, all with default payoffs of zero. Further, after τ_1 has been revealed, the buyer can initiate discussions, and ultimately trade, with either the current supplier or any of the n potential sellers. The presence of the outside suppliers means that the default of b has no impact on the bargaining solution. Rather, the effective default of the seller is zero, as an attempt by the seller to extract any rents will cause the buyer to trade with someone else: the innovation will be implemented and the buyer receives all of the surplus. Similarly, in period $t = 2$ reform also occurs, and all of the surplus accrues to the buyer.

From this we could expect that a seller will never delay the adoption of a general innovation. However, hold-up of a general investment can occur provided there are turnover costs. If an innovation is general, the buyer has a outside option, but this outside option will only affect the division of surplus provided this constraint is binding. If the party with the outside trading option must incur some turnover costs, this option may not be binding. In this case, the threat to implement an outside option would not be credible. This allows the other party to hold-up the general investment (see Malcomson 1997).

Applying this reasoning to the model presented here, a seller might be able to hold-up a general reform provided the buyer must incur some turnover costs if he wishes to trade with another party. Turnover costs, in a sense, reduce a general reform into a specific one. Consequently, delays in the implementation of a general innovation that enhances surplus can occur provided turnover costs are sufficiently large.

In fact, the incentives for the seller to delay a general innovation may be greater than with a party-specific innovation. As a general innovation increases the trading options of the buyer, this could have the effect of reducing the seller's contemporaneous bargaining power (that is, reduce α). As such, a general investment may involve two costs to the seller - a loss in her default payoff and a loss in bargaining power. This increases the cost to the seller of innovation, thus increasing the compensation she requires to agree to $t = 1$ reform. On the other hand, a specific innovation is more likely to leave the relative bargaining strength of each party unchanged, or even enhance the seller's bargaining position, providing her with greater incentive to innovate. In this case, the buyer may have an incentive to delay a specific investment.

3.8.5 Partial reform

Partial innovation may eventuate if there is a set of potential reforms, each with its own payoff and default for the seller. The seller may then choose to trade in some of their defaults but not others. The surplus generated by each innovation may vary differently over time. Alternatively, the default practices or innovations could interact with one another to affect the surplus generated. In this case the seller may opt to introduce a particular subset of innovations at any time. This suggests that strategic bargaining between the parties implementing innovation will affect both the timing and pattern of innovation.

3.9 Applications

The introduction outlined how the print unions delayed the introduction of new printing technology by newspapers in the United Kingdom. This section briefly reviews some additional examples of potential Pareto enhancing innovations that were not implemented, or whose implementation was stalled. In the model presented above delay requires that the seller have the right of veto over whether a project or innovation proceeds. Clearly, this is a strong assumption, and it does not always hold in the examples below. What is emphasized in the examples below is that: delay of innovation is empirically important; parties are concerned about the future consequences of innovation; and, further to that, when parties are unable to write a complete contingent contract these concerns can manifest themselves in opposition to change.

3.9.1 Social policy reform

A significant component of the social policies of Australian governments involve the performance of non-commercial activities, or community service obligations (CSOs), by government business enterprises. In 1997 the cost of CSOs in Australia exceeded \$3 billion (Industry Commission 1997). Governments require government business to perform CSOs in a wide range of areas including postal services, telecommunications, rail transportation and electricity and water services.

CSOs have typically been funded by cross-subsidies and two of the largest CSOs, the uniform charge for the standard letter service within Australia and the telecommunications universal service obligation, are still funded by cross-subsidies. Another major method of funding CSOs is governments accepting a lower rate of return from their trading enterprises that are required to perform these non-commercial activities.

The Industry Commission (1997) recommended that moving to direct funding of these social services would increase total surplus.[†] First, allocative efficiency would be improved by prices in the high margin markets more accurately reflecting costs. Further, cross-subsidies require a restriction of competition in these high margin markets. By directly funding the CSOs from taxation revenue, governments can remove barriers to competition, potentially creating greater incentive for these services to be provided at lower cost. Second, by direct funding CSOs, governments can also introduce competition into the provision of those services.[†] Given these resource savings, direct funding of CSOs would allow these social services to be financed at lower cost or, alternatively, allow the governments to provide more services.

Arguments against explicit funding of community service obligations generally have little to do with the efficiency of that method of provision.[†] Rather, debate

[†]Also see Industry Commission (1991 and 1994) and Productivity Commission (1999) for recommendations regarding specific industries.

[†]Other potential benefits include improved identification and monitoring of CSOs.

[†]Occasionally, it has been argued that, particularly for State and Territory governments, the dead weight loss associated with cross-subsidisation is less than the resource cost of raising the necessary funds through the taxation system.

often centres around the inability for governments to commit to maintaining funding to social causes once they are funded directly from the budget. For example, the Public Sector Research Centre (1988) noted that '[t]he emphasis on cross-subsidies is important as such a mechanism is less exposed to political pressures associated with reducing budget outlays' (p. 15).

Similarly, John Quiggin (1998) argued that:

> The specification of CSOs tends to be a first step towards their elimination ... [a] reason for the vulnerability of CSOs is that CSOs appear as part of the budget sector, whereas the earnings of government business enterprises are 'off-budget'. Governments are typically much more concerned about on budget than off-budget expenditures, even though the economic implications are identical.

Elsewhere Quiggin (1995), referring to Australia Post's uniform pricing policy, argued that 'given that the political pressure to cut measured government expenditure is much greater than the pressure to maximise the returns of government business enterprises ... the maintenance of uniform pricing would not be long-lived'.

In their submission to the Productivity Commission inquiry into the Impact of Competition Policy Reform on Rural and Regional Australia, the Regional Development Council of Western Australia (1998) argued that 'the funding of CSOs though cross subsidisation is of considerable benefit itself ... cross subsidisation avoids the sovereign risk associated with government budget funding, which can be subject to varying political pressures from year to year' (pp. 6-7).

The opinions expressed above directly relate to the model of delays. Many of the arguments against reform presented above relate directly to the incomplete contract assumption in the model above. In these examples governments are, as a result of incomplete nature of the contracting process, unable to commit to a future level of provision of social services. Second, in these examples the status quo provides the recipients of the benefits a default level of utility. Reform would remove this default because with direct funding each year the government needs to decide to provide the funding. Further, the current beneficiaries believe their political influence would be diminished by reform. Prior to reform, responsibility for cross-subsidies generally resides with social welfare departments or the government businesses themselves, rather than expenditure revenue committees who are responsible for explicit spending. Third, it is not feasible to provide up-front compensation for the recipients of these benefits. It is difficult to ascertain who would be the potential beneficiaries in the future, and how much compensation they would require. Furthermore, politically it is infeasible to provide lump-sum transfers to a group such as this for their potential future losses.

Stiglitz (1998) also made the argument that the political process is subject to the market failures discussed in the incomplete contracts literature.[†] In many situations a government is unable to commit to a future policy and it is certainly unable to commit its successor to one. Stiglitz proposes that this contractual incompleteness is one reason why governments are unable to implement Pareto efficient reforms:[†]

> Policy-making is a dynamic process, with today's decisions shaping options and coalitions in the future. In this naive view, a Pareto improvement is a one-shot, static policy change. In reality, it is part of a sequence of policies, and although a reform may be favorable to all groups in earlier stages of the process, it may undermine one or a few groups' interests in later stages. These disadvantaged groups, of course, are often far-sighted enough to anticipate that in the long run they will be worse off and thus act accordingly to oppose a seeming Pareto improvement. (p. 8)

Stiglitz discusses several examples including the provision of subsidised electricity and the removal of price-fixing arrangements in the dairy industry. In each of these examples it possible to compensate the relevant parties, however it is difficult

[†]See Stiglitz (1998), footnote 13.

[†]The other reasons Stiglitz proposes are: coalition formation and destruction in a dynamic bargaining setting; destructive competition (particularly in the political process and other zero-sum games); and uncertainty about the consequences of change.

for the government to commit not to remove direct payments to these groups in the future.

3.9.2 Taxation reform

In recent years in Australia, the Commonwealth Government proposed and implemented a new taxation system. They argued that their proposed reform would create a more efficient system. The centre piece of the proposal was a goods and services tax that would replace, among other things, the current wholesales sales tax. Two issues relate to model presented here. The first relates to the level of the tax. The second relates to the level of compensation for low income earners.

Some commentators, for example Stone (1990) and Moore (1990), have argued against a goods and service tax, even though they believe it is more efficient than the system it is designed to replace, because the government cannot commit to not increase the rate. In fact, in designing its new taxation proposal the Government attempted to design a credible mechanism that would provide some assurance the rate of taxation would not be increased at a later date.[†] These arguments are further evidence of governments' inability to make binding commitments.

Brennan and Buchanan (1977) developed a theoretical model that parallels the policy-based arguments outlined above. In their model individuals vote on a constitution that determines the taxing powers of the government. Once the constitutional rules are in place, the citizens cannot control the actions of the government that acts to maximise revenue, not social welfare.[†] Anticipating this behaviour, the citizens design a tax system (constitution) that limits the ability of the government to raise tax revenue, even if this means instituting an inefficient regime. For instance, a change to a broad tax base improves efficiency and it allows the government to extract more revenue. However, 'it is precisely on such grounds that the changes should be rejected' (Brennan and Buchanan 1977, p. 272).

[†]The Federal Government proposed that a majority of State and Territory governments would have to agree to any increase in the rate of the goods and services tax. This mechanism may not be credible however, as the need for this mechanism can be eliminated by a new Act of Parliament.

[†]The authors called this type of government 'Leviathan'.

The authors compared their predictions with the proposal in the United States of America to replace part of the corporation income tax with a broad-based value-added tax. The tax was rejected, in part due to fears that the new tax would be increased over time to greatly exceed the rate required to replace the old tax (Brennan and Buchanan 1977, p. 272).

Their model has similarities to the model presented in this thesis. First, the choice about the constitution is irreversible, as was the adoption of innovation. Second, there is an incomplete contract in their model as, among other things, the citizens are unable to contract over the government's post-constitution behaviour.

Second, other opponents of the tax changes have made the point that the level of compensation to low income earners and others who will be worse off under the changes will be eroded over time. That is, they argue that the government cannot commit to not revise the compensation package in the future. For example, in its submission to the Senate committee inquiring into the goods and services tax, Anglicare Australia stated that:

> Compensation packages are unlikely to remain intact for long. They require highly visible government expenditure ... there is always pressure on governments to reduce expenditure. This is likely to lead governments of any persuasion to allow inflation to erode compensation packages over time. (p. 6)

As in the social policy examples above, the inability of the government to make binding commitments to future welfare payments was a crucial element to the opposition to taxation reform. Further to that, it was both technically and political infeasible to provide up-front compensation to welfare recipients.

3.9.3 Workplace reform

Unions are typically thought to oppose innovation. For example, Pollard (1982) suggested many unions accept technical change 'only after bitter struggles' (p. 107). However, unions may react to an innovation with obstruction, competition, control or encouragement, depending on how they expect to fare from the change (Slitcher and Healy 1960). Much of the bargaining between unions and firms boils down to attempting to maintain or improve present and future relative bargaining positions. Far from being irrational, as it is often argued, surplus reducing behaviour may well be necessary for a party to maximise its total expected surplus.

In relation to the adoption of workplace reform there are several key issues. First, it must be ascertained to what extent the union can influence innovation in the workplace.[†] Of course, as well as outright rejection a union or employee can resist complete implementation of the new technology, stall its introduction or attempt to have old inefficient workpractices maintained after the change. Second, a union's reaction to innovation depends on how they expect to fare from the change (see Dowrick and Spencer 1994). Clearly, a union must have both the incentive and the means to be able to effectively delay change.

There are three main points of this sub-section. First, as a general rule innovations are either 'product' or 'process' (cost-reducing) innovations (Willman 1986). In process innovating industries, change is generally associated with attempts to increase product demand and, as a consequence, increased demand for labour. Willman argued that these innovations are rarely opposed by unions. Cost-minimisation innovations, on the other hand, typically involve reducing the demand for labour, often by replacing labour with capital. It is 'cost-reducing' innovations that unions generally oppose.

Second, contractual incompleteness matters. Spot markets provide opportunity for unions to hold-up the firm. However, they also provide an opportunity for the firm to renegotiate, for example to decrease their labour requirements. With process innovation (labour saving or cost-cutting innovation) unions anticipate a potential reduction in employment. Consequently, without a credible commitment to maintain staffing levels or adequate compensation, unions oppose these changes. It may be difficult for firms to make these commitments: in particular, employers

[†]See Cornfield (1987b) and Batstone and Gourlay (1986) for a review of the potential influence of unions over managements' decision to adopt new technology.

are often limited in their ability to commit to future wages or employment levels.[†]

Third, a craft union is more likely to delay or resist innovation than a more broadly based union. A union that is most likely to lose out from a change in workpractices is one that faces a drastic innovation or one that severely reduces their default position. As such, the model predicts that profession-based unions facing a drastic new technology would be more likely to oppose change. Dowrick and Spencer (1994) also argued that a craft-based union are more likely to oppose change. Similarly, Batstone and Gourlay (1986) argued that:

> we would expect that, for example, a single-occupation union, particularly of craft workers, would place greater emphasis upon the preservation of skill and job territory, so that it would demonstrate a greater concern over such matters as training and work organisation (p. 37).

3.9.4 Waterfront reform

After World War II, in the United Kingdom dockside workers were employed casually. This system evolved due to the unpredictable nature of demand that would fluctuate with how many ships were in port. Most workers were employed by a 'holding employer' (the dock labour board), who would make fall-back payments when there was no work, and an 'operational employer', who provided the docker with the actual work. Over time, however, the number of excess dockers fell as final-product demand increased. With their increased market power, the unions increased the numbers of employed, extended the length of work and increased wages. The restrictive practices included: inflated staffing scales; controls on the hiring process; restrictions on working hours; extended tea breaks; and spinning out of work by

[†]Cornfield (1987a) argued that:

> Throughout the course of U.S. industrialization, workers and managers have attempted to control the implementation and outcomes of technological change ... fearing displacement and loss of income, workers have sought control of technological innovation in order to maintain their job security. (p. xi)

'welting' and 'spelling', effectively increasing the labour required to complete any task (Willman 1986, pp 109-112).

The Delvin reforms, implemented in two stages in 1967 and 1970, attempted to remove casualisation and secured permanent employment for most dockers. These reforms partially paved the way for the introduction of containerisation - a technical innovation that would rapidly decrease unloading times and threaten to 'eliminate dockworkers from the chain of transport' (Fadden 1976, p. 313, as cited in Willman 1986, p. 116). The introduction of new technology was banned until Phase II of the reforms were negotiated, and these were only accepted after a national dock strike in 1970. Along with the new technology came a new employment agreement in the form of a comprehensive contract, including 'contingency payments'. Although this contract did not end disputes or restrictive practices (dockers tried to extend their sphere of influence and many practices like over-staffing, lack of gang mobility and demarcation between trades remained, Willman 1986, p. 117) it was a significant step away from spot-market contracts, which provided an opportunity to continuous renegotiate and stall reform, to more contingent contracts, which provided labour with more of the assurances they were looking for.[†]

In the United States longshore industry there are two major unions: the International Longshoremen's Association, who represent union members on the East and Gulf coasts; and the International Longshoremen's Warehousemen's Union represents workers on the west coast. According to Waters (1993) over the last 30 years the International Longshoremen's Association resisted technical change while the International Longshoremen's Warehousemen's Union cooperated with implementing change (p. 264). Whereas the International Longshoremen's Warehousemen's

[†]Willman (1986) argued that:

> Although the system could cope with day-to-day change where ship turn-around was more important than labour cost, in the long term the delays promoted by the contractual system stimulated its demise. In the short-term, spot contracting was a suitable response to product market variance; in the longer term, the needs of shipowners for rapid jobs finish ran into conflict with the labour-market necessities of job expansion and creation. (p. 118)

Union decided to invite mechanisation and concentrate its efforts to ensure job security, improved working conditions and higher wages, the International Longshoremen's Association viewed containerisation as a threat to job security, tried to maintain employment and tried to increase wages (pp. 262-264).[†]

Wharves in Australia have not been without conflict either. The Australian waterfront was essentially a double-monopoly. The Maritime Union of Australia controlled the supply of labour while Patrick Stevedores and P&O Ports accounted for 90 per cent of container business in a cosy duopoly (Trinca and Davies 2000, p. 5 and p. 30). In this environment of limited competition, the Maritime Union of Australia used its almost complete employee coverage and the high cost of berthing stoppages or delays to extract favourable terms and conditions for its members (Productivity Commission 1998a, p. xxix and p. 138).

Despite attempts to reform the waterfront in the 1980s and early 1990s, there was still potential for significant reform. For example, productivity of Australian wharves compared unfavourably to the rest of the world (Productivity Commission 1998b). Many of the inefficient workpractices in the container stevedoring industry, such as inflexible work arrangements, reduced productivity, reliability and increased labour costs.[†] Further, overtime was also an important, and expected component, of salaries (Trinca and Davies 2000, p. 21 and p. 25).[†] The potential benefits of reform were well known to the stevedores, the Federal Government and the union itself (Trinca and Davies 2000, p 5). Despite this, the Maritime Union of Australia effectively stalled comprehensive reform.[†] The limited degree of private information in this situation strongly suggests that the asymmetric information story cannot

[†]Interestingly, the members of the International Longshoremen's Association were better off than their counterparts in the short-run. However, in the long run members of the International Longshoremen's Warehousemen's Union earned more than East coast dockers (Waters 1993, p. 265, p. 269).

[†]For example, on the waterfront there was a long-established practice of 'the nick' that involved wharfies leaving work early when ships were loaded (Trinca and Davies 2000, p 5)

[†]In 1996-97 stevedore workers earned on average between $60 000 and $100 000. 20 to 30 per cent of these amounts were overtime payments (Productivity Commission 1998a, p. xxi). Overtime payments were significantly larger than productivity payments (Productivity Commission 1998a, p. xxv).

[†]For instance, the Productivity Commission (1998a) argued that strong union bargaining power was an important impediment to change (p. xxix). Also see Trinca and Davies (2000).

effectively explain the union's attitude towards reform.

The dispute came to a head in 1998 with the lockout of Maritime Union of Australia members by Patrick Stevedores. The stevedore wanted to improve productivity by introducing new computerised terminals, alter working conditions and reduce the workforce.† Reform would have two effects on the union's claim on future surplus. The existing system provided the union members with a high default payoff (b). Second, removal of the closed shop would reduce the union's contemporaneous bargaining power (α). These future losses for workers were accentuated by the relatively low turnover of stevedore workers (Productivity Commission 1998a, p. 17). To entice the union to agree to the change the Stevedore would need to provide significant compensation. However, Patrick Stevedores did not have the required money to pay the payments required by the existing redundancy agreement.† For example, in six months in 1997 the company lost \$3.6 million at the Melbourne docks alone. This suggests that Patrick were severely limited in their ability to raise the funds to provide the union members with sufficient up-front compensation. This inability to compensate workers, coupled with the significant potential future losses, provided the union with the incentive to delay innovation.†

†Patrick Stevedores anticipated that the new technology would reduce the need for labour at its bigger ports from 400 to 40 workers (Trinca and Davies 2000, p. 25).

†The Productivity Commission (1998a) argued that 'redundancy payments' were part of the work arrangements that retarded performance in the stevedoring industry (p. xxvii). However, from the theory, these payments may simply be compensation for future losses, in which case they could aid the efficient implementation of new technology rather than impeding it. Although exorbitant redundancies may be a means of stalling reform, the model suggests that if adequate compensation can be paid delay will not be observed. Patrick Stevedores estimated that redundancy packages to members of the Maritime Union of Australia were on average \$73 000, while redundancies to Australian Maritime Officer's Union members were on average \$190 000 (Productivity Commission 1998a, p. xxii).

†In April 1998 Patrick Stevedores attempted to bypass the Maritime Union of Australia by generating a dispute, sacking its workforce and establishing a non-union stevedore. This plan had the support of the Federal Government who, amongst other things, legislated to pay redundancies. This was deemed unlawful by the Federal and High Courts and the dispute was finally resolved in September 1998 (Trinca and Davies 2000, pp. xi-xii).

3.9.5 Computer technology

Computer technology has undoubtedly changed production in many industries as well as creating many new jobs. Resistance to computer technologies have typically come from workers who fear that the new technology would replace them. Australian telecommunications workers went on strike in 1977 against a new computer system that threaten a number of jobs (Sale 1995, pp. 252-53). The dispute ended with a moratorium on the new machines, although they were eventually introduced with a few job terminations (Sale 1995, p. 253). Similarly, in England at the Lucas Aerospace plant unions successful sort a moratorium on new computerised machines, although it lasted less than a year. Willman (1986) examined the reaction of unions to the introduction of computer technology in mature industries and concluded that 'conflicts over change ... arose primarily because of the inability of contractual forms to accommodate changing economic and technical conditions' (p. 179).

3.9.6 Automobile industry

Product market innovation in the automobile industry, such as the development of new models, go hand-in-hand with process innovation (p. 149). The automobile industry in the United Kingdom provides an interesting case study because different firms took alternative approaches to contracting with their labour force, with different implications for the adoption of innovation.

The United Kingdom producers typically used spot-market contracts, sequentially negotiated, with these negotiations often involving shop stewards. On the contrary, Ford in the United Kingdom negotiated at the national level, on a company-wide basis, a comprehensive annually negotiated pay deal, with relations between bargaining dates regulated by a detailed book of rules. The effect of this was greater stability in wages and employment than experienced by its United Kingdom-owned counterparts. In this way Ford was able to insulate employees from demand fluctuations. Willman (1986) concluded that, as a consequence, Ford avoided many of the difficulties associated with innovation experienced by the U.K.-owned manufacturers. For example, Willman (1986) stated:

> Recurrent process and product innovation generated conflict over technological change. However, only part of the UK industry was affected. This part, British owned and reliant on spot contracting, could be contrasted with the US-owned sector of the industry, particularly Ford, as well as with the industry in the USA itself. American Car manufacturers tended towards comprehensive contingent claims contracts which appeared to leave employment and earning much less susceptible to product-market change. (p. 248)

3.9.7 Wide-comb shears

By law, shearers in Australia were not permitted to use combs wider than 64 mm. From the 1960s, however, wide-comb shears were beginning to be used illegally, particularly by New Zealand shearers. Evidence suggested wide-combs were more efficient: for example, a University of New England study found that 'wide combs result in a reduction in time required to shear in the order of 17 per cent, cause no significant time reduction in the quality of the shearing job, and cause no increase in the proportion of skin cuts' (as reported in Hearn and Knowles 1996, p. 316). Despite this, the shearers' union, the Australian Worker Union, vehemently opposed the use of wide-comb and ensured the existing award conditions were upheld where possible (Hearn and Knowles 1996, p. 304 and pp. 314-315).

In 1982 an application was made to change the Pastoral Industry Award to officially allow the use of wide-comb shears. This application was again opposed by the Australian Worker Union. The change in law was seen by the union as an erosion of workers' contractual rights - in terms of the theory, it was an attempt to reduce b. Not only that, the issue was seen by the union as a part of a campaign to reduce their rights generally.†

†In May 1982 the Australian Workers Union commented that '[i]n no time we'll be back to the conditions the industry had before 1990' (as reported in Hearn and Knowles 1996, p. 316).

As in the other examples above, there was little scope for the industry to pay compensation to the union for its future losses. As well as the itinerant nature of shearing, the industry was suffering financially in 1982, hit by low commodity prices and drought (Hearn and Knowles 1996, p. 314). Further, as suggested by the theory, maintaining their default conditions was important for the shearers as they worked in an industry in decline. For instance, in 1956 a shearer could earn double the average weekly wage: in 1986 shearers earned little more than average weekly wages (Hearn and Knowles 1996, pp. 313-14.)

In December 1982 the Arbitration Commission ruled to allow combs wider than 64 mm. Upon losing its appeal in March 1983, union members went on strike for 8 weeks in a unsuccessful attempt to reverse the court's decision.

3.9.8 Other restrictive workpractices

Where the removal of restrictive workpractices would increase the total surplus available, the parties are forgoing a potential bargaining opportunity. There are many other examples of this in Australian industry, see for example Productivity Commission (1998c, pp. xx-xxiv and Chapter 8) for restrictive workpractices in the Australian Processing Industry and Productivity Commission (1998d, pp. xxvii-xxxiii and Chapter 5) for work arrangements in the black coal industry.

3.9.9 Summary

To conclude this section, it is worth reiterating some of the points of these examples. First, delay in bargaining (or innovation) is empirically relevant, both in terms of numbers and in terms of the loss in overall surplus. Second, the assumptions of the model are supported by the case studies presented. Note that in the restrictive workpractice and social policy examples presented there was generally common knowledge about the benefits of reform. As such, the asymmetric information story of delays in bargaining is not always applicable. Further, the incompleteness of contracts is an important factor in determining unions' opposition to change. In fact, the type of contracts used in an industry would often have to change to allow change to proceed. Willman (1986) argued that:

> Conflict over change is particularly likely where two conditions exist. On the one hand, cost-cutting process innovations are more likely to generate resistance than product change: expanding sectors where product rather than process change predominates are less likely to experience problems. On the other hand, spot-contracting bargaining structures which transmit product-market volatility through to wages and employment, and which allow continuous union influence over job content, are more likely to generate conflict.
>
> All three industries [docks, newspaper, motor vehicles] experiencing a high level of conflict over change were characterized by product-market volatility and spot contracting. In all cases, technological change which cut costs was accompanied by organizational change which sought to move away from spot contracting to a more comprehensive contract. (pp. 247-48)

The question then remains as to why the contractual environment does not immediately adjust to facilitate change. Notably, all the industries discussed (the waterfront, newspaper printing and automobiles) struggled over many years to implement more fully-contingent contracts in an attempt to overcome these problems.

Third, the predictions of the model are consistent with the evidence, namely that craft unions were more likely to oppose change than union with a broader range members. Again, Willman (1986) argued:

> In spot contracting, for example, trade unions must almost by definition be decentralized: the requisite form of bargaining puts pressure on local negotiators. Given its origin in product-market variation, trade unions are highly likely to become concerned with job control and to seek to bargain over work-loads and employment levels. Incremental technical change is a bargaining opportunity, but contractual change

must involve a substantial power shift away from local representatives towards those who will design and administer a comprehensive contract. (pp. 253-54)

3.10 Conclusions

The model developed in this paper generates delays in bargaining with: multiple bargaining rounds; incomplete contracts; and wealth constraints. Unlike much of the non-cooperative bargaining literature, delays may occur in equilibrium without the presence of asymmetric information.

The model consisted of two periods and a buyer and seller. At the start of each period a potential new reform or task was revealed to both parties, along with the surplus that it could generate. If the parties agree to adopt the new innovation, they bargained over the potential surplus. A party's claim on surplus depended on their default payoff and their bargaining strength. An effect of innovation was that the seller lost her default payoff (in the basic model) or her contemporaneous bargaining power (in the extended model).

If the seller anticipates losing out in subsequent bargains from first period reform, she will be only willing to accept innovation if she is adequately compensated. This may not be possible because of wealth constraints. Further, because the parties cannot write a fully contingent contract, they are unable to implement reform on the basis of a surplus sharing arrangement or a commitment to a future remuneration scheme.

The basic model predicts that the incentive to delay for the seller is increasing in the outside option, decreasing in current bargaining strength, decreasing in expected surplus and increasing in the probability that future surplus is low. Allowing (drastic) innovation to affect the relative bargaining power of the parties alters these results. If innovation reduces the bargaining power of the seller, she is more likely to delay when surplus is expected to be higher in the future (relative to the present potential surplus). Similarly, a seller is more likely to delay a drastic innovation the higher the level of her current bargaining strength.

3.11 Appendix A

Result 3.1 *Innovation will always occur in period $t = 2$, regardless of the outcome in the first period.*

Proof. Consider the case when innovation has not occurred in the first period. If the parties decide not to innovate at $t = 2$ the payoffs for the seller and buyer are b and 0 respectively. If there is innovation at $t = 2$ the payoffs depend on the realisation of v_2 and the relative size of b. From equation 3.1 and 3.2, the payoffs for the buyer and seller are either: $\{\alpha v_2, (1-\alpha)v_2\}$ if $\alpha v_2 \geq b$; or $\{b, v_2 - b\}$ if $b > \alpha v_2$. Thus both the buyer and the seller weakly prefer innovation over the status quo, given no innovation occurred in period $t = 1$.

Now consider the case when innovation occurred in period $t = 1$. If period innovation $t = 2$ does not occur the payoffs to the buyer and seller are zero. If $t = 2$ innovation occurs the payoffs to the seller are $\{\alpha v_2, (1-\alpha)v_2\}$. Both players strictly prefer period $t = 2$ reform if innovation occurred in period $t = 1$. □

Result 3.2 *The buyer never wishes to delay innovation in the first period.*

Proof. Consider the first period payoffs. If no $t = 1$ innovation occurs, the buyer's $t = 1$ payoff is zero. From equations 3.1 and 3.2, if innovation occurs in period $t = 1$ the buyer's payoff is either: (i) $(1-\alpha)v_1 - F_1$; or (ii) $(v_1 - b) - F_1$. From Assumption 3.5, in case (i) $F_1 \leq (1-\alpha)v_1$ and in case (ii) $F_1 \leq (v_1 - b)$. Consequently, the buyer's first period payoff if there is innovation is greater than or equal to his no innovation payoff (zero).

Now consider the effect on second period payoffs from first period innovation. From Result 3.1, innovation will always occur in equilibrium in the second period. To assess the impact in the second period of $t = 1$ reform, the buyer must compare the expected payoffs given by equation 3.1 or 3.2 (no-innovation payoffs) with the expected return given by equation 3.3. If the relevant no-innovation payoffs are given by equation 3.1, there is no change to the second period payoff from innovation in the first period. (The outside option for the buyer is not binding.) If, on the other hand, the relevant no-innovation payoff is given by equation 3.2 the buyer is better off in the second period from $t = 1$ reform, as $(1-\alpha)v_2 - (v_2 - b) = b - \alpha v_2 > 0$. The buyer's claim on second period surplus is weakly improved by $t = 1$ innovation.

Taking into account the effect of $t = 1$ reform on the buyer's payoff in both periods, the buyer strictly prefers first period innovation as he has an expected positive gain from innovation in at least one period. To see this, assume F_1 is equal to the entire size of the buyer's first period surplus. When $b > \alpha v_H$ the two period return to the buyer if there is $t = 1$ innovation of $[0 + p(1-\alpha)v_L + (1-p)(1-\alpha)v_H]$ exceeds his payoff over both periods when there no first period reform of $[0 + p(v_L - b) + (1-p)(v_H - b)]$. Similarly, when $\alpha v_L < b < \alpha v_H$, the return to the buyer with first period innovation exceeds the no-innovation return, as $[0+p(1-\alpha)v_L+(1-p)(1-\alpha)v_H] > [0+p(v_L-b)+(1-p)(1-\alpha)v_H]$. Therefore, the buyer never wishes to reject innovation in the first period. $\square$

Result 3.3 *(a) If $v_1 = v_L$, the seller will accept innovation in the first period when: (i) $b < \alpha v_L$; (ii) $\alpha v_L < b < \alpha v_H$ and $b \leq v_L\frac{(1+\alpha p)}{(1+p)}$; and (iii) $v_L > b > \alpha v_H$ and $b \leq \frac{1}{2}(v_L + \alpha v_2^e)$. (b) The seller will delay innovation in the first period when $v_1 = v_L$ if: (i) $\alpha v_L < b < \alpha v_H$ and $b > \frac{v_L(1+\alpha p)}{(1+p)}$; or if (ii) $v_L > b > \alpha v_H$ and $b > \frac{1}{2}(v_L + \alpha v_2^e)$.*

Proof. First, consider the seller's decision when $v_1 = v_L$ and $b < \alpha v_L$. Let U_D^S be the seller's ex ante expected utility when she does not agree to the first period innovation. Also, let U_A^S be the seller's ex ante expected utility when she does agree to the period $t = 1$ innovation. If the seller rejects first period innovation $U_D^S = b + \alpha v_2^e$. In the first period the seller receives her default payoff b. In period $t = 2$ the seller expects to receive αv_2^e as her outside option never binds. If the seller agrees to the first period innovation, $U_A^S = \alpha v_L + F_1 + \alpha v_2^e$. Again, the seller's outside option is not binding at time $t = 1$. Letting $F_1 = 0$, $\Delta U = U_D^S - U_A^S = b - \alpha v_L < 0$. As $\Delta U < 0$, the seller will be worse off if she delays the first period innovation, even without any compensation payment. The seller will always agree to $t = 1$ innovation in this case, as in Result 3.3(a) part (i).

Second, consider the seller's decision when $v_1 = v_L$ and $\alpha v_L < b < \alpha v_H$. Here, $U_D^S = b + pb + (1-p)\alpha v_H$. If the seller delays first period innovation her outside option will be binding only if $v_2 = v_L$. As before, she receives her default payoff in the first period. On the other hand, $U_A^S = b + F_1 + \alpha v_2^e$. Once, innovation has occurred, the seller's expected second period surplus is given by equation 3.3. In the first period the outside option is binding, so the seller will receive this payoff, plus any fixed payment from the buyer. From Remark 3.5, the buyer is willing to set F_1 equal to his total share of surplus $(v_L - b)$ if necessary. If $F_1 = v_L - b$, $\Delta U = b + pb + (1-p)\alpha v_H - v_L - \alpha p v_L - \alpha(1-p)v_H = b(1+p) - v_L(1+\alpha p)$. The seller will agree to innovation if $\Delta U \leq 0$, or when $b \leq \frac{v_L(1+\alpha p)}{(1+p)}$. This demonstrates Result 3.3(a), part (ii). The seller will delay if $\Delta U > 0$, or if $b > \frac{v_L(1+\alpha p)}{(1+p)}$, showing Result 3.3(b) part(i).

Third, consider the seller's when $v_1 = v_L$ and $b > \alpha v_H$ (also note $b < v_L$). If the seller delays in the first period, her expected surplus is $U_D^S = b + b$. Here, the outside option will be binding in the second period regardless of the value of v_2. Again, if innovation is delayed at $t = 1$, the seller receives her default payoff in the first period. If the seller agrees to innovation at $t = 1$, $U_A^S = b + F_1 + \alpha v_2^e$. In the first period, the seller receives surplus equal to her default, plus any transfer from the buyer F_1. In the second period the division of surplus is given by equation 3.3. Again, to see if there is an equilibrium involving delay, consider when $F_1 = v_L - b$, the largest feasible transfer from the buyer in this case. With this compensation payment $\Delta U = 2b - v_L - \alpha v_2^e$. The seller will delay innovation if $\Delta U \leq 0$, or if $b \leq \frac{1}{2}(v_L + \alpha v_2^e)$, as in Result 3.3(a) part (iii) Conversely, the seller will delay first period reform if $\Delta U > 0$, or if $b > \frac{1}{2}(v_L + \alpha v_2^e)$, as in 3.3(b) part (iii). □

Result 3.4 *(a) If $v_1 = v_H$, the seller never wishes to delay when: (i) $b < \alpha v_L$; (ii) $b \in (\alpha v_L, \alpha v_H)$ and $b \leq (\alpha p v_L + v_H)/(1+p)$; and if $b \in (\alpha v_H, v_L)$ and $b \leq \frac{1}{2}(v_H + \alpha v_2^e)$. (b) If $v_1 = v_H$, the seller will delay first period innovation if: (i) $b \in (\alpha v_L, \alpha v_H)$ and $b > (\alpha p v_L + v_H)/(1+p)$; (ii) or if $b \in (\alpha v_H, v_L)$ and $b > v_H \frac{(1+\alpha(1-p))}{2} + \frac{\alpha p}{2} v_L = \frac{1}{2}(v_H + \alpha v_2^e)$.*

Proof. Consider when $v_1 = v_H$ and $b < \alpha v_L$. If the seller delays innovation in the first period her expected utility is $U_D^S = b + \alpha v_2^e$. She receives her default payoff in the first period and, as her outside option will never be binding, her expected claim on second period surplus is αv_2^e. If the seller accept first period innovation, her expected utility is $U_A^S = \alpha v_H + F_1 + \alpha v_2^e$. As the outside option is not binding, the first period claim on surplus is αv_H plus F_1. Second period expected surplus is given by equation 3.3. Letting $F_1 = 0$, $\Delta U = b + \alpha v_2^e - (\alpha v_H + \alpha v_2^e) = b - \alpha v_H < 0$. Reform is in the seller's interests, even without any fixed payment from the buyer, so she will always agree to implement reform at $t = 1$. This demonstrates 3.4(a) part (i).

Now consider when $v_1 = v_H$ and $b \in (\alpha v_L, \alpha v_H)$. If the seller delays $t = 1$ innovation her expected utility $U_D^S = b + (pb + (1-p)\alpha v_H)$, where $(pb + (1-p)\alpha v_H)$ is her expected second period surplus given that the outside option is only binding when $v_2 = v_L$. If the seller agrees to first period reform $U_A^S = \alpha v_H + F_1 + \alpha v_2^e$. Here, $\alpha v_H + F_1$ is the first period payoff with innovation as the default is not binding. Upon first period agreement, the seller's second period surplus is αv_2^e. Considering the largest feasible F_1, that is $F_1 = (1-\alpha)v_H$, $\Delta U = b - \alpha v_H + (pb - \alpha v_L) - (1-\alpha)v_H = b(1+p) - \alpha p v_L - v_H$. The seller will accept period $t = 1$ innovation if $\Delta U \leq 0$, or if $b \leq (\alpha p v_L + v_H)/(1+p)$, as in Result 3.4(a) part (ii). The seller will delay first period reform if $\Delta U > 0$, or if $b > (\alpha p v_L + v_H)/(1+p)$, as in Result 3.4(b) part(ii).

Finally, consider when $v_1 = v_H$ and $b \in (\alpha v_H, v_L)$. If the seller delays her expected utility is $U_D^S = b + b$. If the seller accepts reform in the first period her expected utility is $U_A^S = (b + F_1) + \alpha v_2^e$. Considering the largest feasible fixed payment, $F_1 = v_H - b$, $\Delta U = b + b - [v_H + \alpha p v_L + \alpha(1-p)v_H] = 2b - v_H - \alpha p v_L - \alpha(1-p)v_H$. The seller will accept reform if $\Delta U \leq 0$, or if $b \leq \frac{1}{2}(v_H + \alpha v_2^e)$, as in Result 3.4(a) part (iii). The seller will delay $t = 1$ reform if $\Delta U > 0$ or if $b > \frac{1}{2}(v_H + \alpha v_2^e)$, as in Result 3.4(b) part(ii). □

CHAPTER 4

The determinants of innovation: empirical evidence from AWIRS 95

4.1 Introduction

At times innovation is contentious as it alters the distribution of surplus. For example, a union may oppose reform if it weakens their bargaining strength or reduces their share of surplus, even if the innovation increases overall welfare. Using the Australian Workplace Industrial Relations Survey 1995 (AWIRS 95), this chapter examines resistance to workplace innovation.

Resistance to change takes different forms and can have varying impacts.† This chapter studies three aspects of innovation. First, opposition to reform may lower rates of innovation (Willman 1986, p. 38). With this in mind, the paper compares the characteristics of workplaces that adopted an innovation of some sort with those that do not. It is then possible to infer the features that encourage employees or unions to resist change. Second, where innovation did occur, the chapter examines the attitudes of employees to these innovations. This allows us to study situations in which labour would have vetoed change if they were in a position to do so. Third, this chapter examines the characteristics of workplaces that wished to implement some change but were prevented from doing so. This analysis provides a direct

†Willman (1986) argued that resistance to innovation could take different forms, including: (i) companies dissuaded to innovation given their expectation of excessively costly union/employee resistance; (ii) firms factoring higher pay for employees operating the new equipment into the cost of innovation; and (iii) firms altering innovations because of the expectation that the benefits of innovation will be reduced due to the maintenance of restrictive workpractices (pp. 5-6).

measure of union or employee resistance to the introduction of surplus enhancing innovations.

Although of interest by itself, this chapter provides an empirical test of the theoretical results of the model presented in the previous Chapter 3. This study also contributes to the existing literature in several other important ways. First, the chapter explores innovation using a new data source, AWIRS 95. Second, as far as the author is aware, this is the first time attitudes towards innovation and a direct measure of delay have been used in such a study.

The paper is structured as follows. Section 4.2 briefly reviews previous studies of workplace innovation. Section 4.3 outlines the empirical predictions arising from the theory of delays in innovation with incomplete contracts, presented in detail elsewhere. These predictions provide a framework for the empirical estimation and discussion to follow. The AWIRS data and the dependent and independent variables used are described in Section 4.4. The empirical estimation results are presented in Section 4.5. Finally, Section 4.6 makes some concluding comments.

4.2 Previous studies

This section reviews several studies that have examined the determinants of innovation.

Using the Workplace Industrial Relations Survey (WIRS) conducted in the United Kingdom over the period 1981-84, Machin and Wadhwani (1991) examined the determinants of organisational change defined as 'substantial changes in work organisation or work practices not involving new plant, machinery or equipment'. As independent variables they included: union involvement in bargaining with the workplace management; a financial performance dummy; the number of competitors; a dummy if product demand was increasing or contracting; and a variable indicating whether the plant was operating at full capacity. As well as industry dummies Machin and Wadhwani included data on the local market unemployment rate on the basis that this would affect a union's ability to bargain effectively with a firm and veto change.[†]

Their estimations showed that establishments with recognised unions were more likely to have implemented organisational change, as were larger plants, poorly performing plants and foreign owned plants. The regional unemployment variables were insignificant. Although noting the positive effect of the union variable, the authors qualified this result by commenting that the union movement was in decline over the survey period due to rising unemployment, anti-union legislation and a weakening product market. Further, since unionised workplaces had more restrictive workpractices at the beginning of this period, those plants had greater opportunity to implement organisational change (p. 843). The authors argued that this implies that unions in decline were less likely to discourage investment.[†]

Nunes, Crockett and Dawkins (1993) used the Australian Workplace Industrial Relations Survey 1990 (AWIRS 90) to test whether organisational technical change was more likely in workplaces in the traded sector, in the private sector or in competitive areas of the economy.[†] They also tested whether trade unions have a positive or a negative effect on innovation.

They created seven dependent variables depending on whether or not a workplace had recently introduced: significant changes in the product or service; new plant, equipment or office technology; a major restructuring of how work was done; job redesign; an incentive/bonus scheme; semi-autonomous work groups; or quality circles/team building at the workplace.[†] Logit estimations were made with these seven dependent variables. In addition, they created three reform indexes by combining responses to the seven possible changes.[†] These indices where used to identify

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[†]Unemployment nearly increased three-fold between 1979 and 1982 in the United Kingdom (Machin and Wadhwani 1991).

[†]In 1995, Australian unions were also undergoing significant changes, with the progressive implementation of certified and enterprise bargaining. Union membership was also in decline. (See Morehead et al 1997 Chapters 1 and 7.) Consequently, the results presented here need to consider the effect of the changing environment on union behaviour. However, the reliance on labour's ability to veto change is partly circum~~navigat~~vented by also analysing union and employee attitudes to innovation.

[†]Also see Crockett et al (1993).

[†]The first three changes were to be introduced within the last two years while the last four changes could have been introduced within the last five years.

[†]The first index combined the first three changes (changes in product or service, new plant or

whether a workplace had a propensity to make many changes. An ordered probit was run on these three indexes.

The independent variables used included: the level of competition; import, export and private sector dummies; union presence in the workplace; the number of unions; union density; size of the workplace and its age; the size of the organisation; whether demand for the product was changing (increasing or contracting); and industry dummies.

The alternative dependent variables yielded different results. For example, union presence was positively associated with the probability that a workplace adopted a product change. In comparison, when process change was used as the dependent variable the coefficient on union density and presence was negative; but for the numbers of unions it was positive. Other results included: workplaces from larger organisations were more likely to implement a product innovation; workplaces that were experiencing some change in demand were more likely to implement a product innovation; process innovation was more probable in larger workplaces, older workplaces and when demand was changing; organisation size was positively associated with the probability of work restructuring; and, finally, job redesign was positively associated with workplace size but negatively associated with being in the competitive sector and with high workplace autonomy.[†] Further, the results for the ordered probits estimations, using the three reform indices suggested a change in management, good management-union relations, workplace size and the changing demand variable were all positively associated with a higher probability of innovation, while union density and the high autonomy variable coefficients were negative and significant.

Using AWIRS 1990, Drago and Wooden (1994) found that unions had a negative effect on innovation and investment. They established that investment levels were

equipment and major restructuring of work). The second index contained the other four possible changes (job redesign, incentive/bonus scheme, semi-autonomous work groups and quality circles). The final index included all seven possible changes.

[†]Willman (1986) argued unions would oppose process innovation as it were likely to cost jobs, but that they would be more accepting of product innovations that were likely to increase demand for both the final product and for labour.

higher in workplaces where unions were active. Using the introduction of major new plant, equipment or office technology as the dependent variable, they found that size of a workplace had a positive effect; higher rates of return were positively associated with change, rising demand was positively associated with change while there was a small positive effect of falling demand.[†] Overall, these results were similar to Machin and Wadhwanis' (1991) findings in the United Kingdom.

Brooks and Morris (1993), again using AWIRS 1990, examined the determinants of whether or not a workplace introduced major new plant equipment or office technology in the previous two years for all workplaces, manufacturing workplaces and non-manufacturing workplaces. Their union variables gave mixed results in all three samples. For example, when all workplaces were examined union presence had a significant and negative effect on technical change, whereas increases in the number of unions in a workplace a significant and positive effect. Union density was, however, not significant. Market growth had a positive and significant effect on the probability of innovation for all three specifications, while the variable for a declining market was not significant for any of the estimations. Product demand predictability had a positive effect on innovation in two of the three specifications. Variables proxying for competition levels, including traded sector dummies, were positive for some specifications, but they were not always significant. Interestingly, Brooks and Morris used as explanatory variables several proxies for innovative management, including whether the workplace had introduced new products, new work practices and just redesign, that were used as dependent variables by Nunes et al (1993).

In summary, there is mixed empirical evidence about the impact of unions on innovation. Some evidence from the United Kingdom suggests that unions are positively associated with change. On the contrary, it appears that Australian unions have often been associated with lower rates of innovation. This conclusion is far from definitive, however, as some evidence suggests unions have been positively associated with change for some alterative innovations and union variable specifica-

[†]They also found that foreign-owned workplaces were less likely to have implemented some innovation.

tions. The size of the workplace and the organisation is often positively associated with innovation. The probability of innovation is often positively associated with competition and with workplaces in the traded sector.

4.3 Theory

This section briefly outlines the theory of delays in innovation presented in detail in Chapter 3. Consider the following example. A firm wishes to implement an innovation that increases total surplus. This innovation may be the introduction of a new technology or a new workplace procedure. This innovation will also, by its very nature, reduce employee's bargaining power in future negotiations, thus reducing their claim on future surplus. As a result, to induce agreement the firm must compensate the employees for their future expected losses. If the firm cannot provide this compensation up front, or commit to a contract in the future that provides the necessary compensation, employees will resist making the change.

The key elements of the model are that: there are multiple bargaining periods; the outcome of previous bargaining rounds affects the subsequent distribution of surplus; contracts are incomplete; and the parties are wealth constrained. Thus, in a reduced-form equation the probability of whether a workplace innovates can be written as:

$$Pr(innovation) = f(finance, surplus, bargaining\ power)$$

In this equation the probability of innovation (or the probability of no delay) is a positive function of a workplace's access to finance. The specific relationship between delay, future surplus and bargaining power are described below.

The predictions of the model provide a framework to analyse the empirical results in this chapter. In the model reaching agreement (innovation) affects parties' claim on future surplus either by altering their default payoffs (historical bargaining positions) or by changing their relative contemporaneous bargaining strengths. Delay will occur at different times depending on which of these assumptions applies.

First, if innovation reduces the default payoffs of a party, delay is more likely ~~when~~ the larger the ~~this~~ default ~~is larger~~, as outlined in Prediction 4.1.

Prediction 4.1 *A party with a strong historical position is more likely to delay innovation.*

If innovation reduces labour's default position this could reduce their claim on surplus in the future, providing possible incentive for delay. An innovation of this sort might be the removal of a restrictive workpractice that allows employees leisure on the job, excessive staffing levels or outdated work-safety rules. The sort of unions we could expect to behave like this are older unions that won major concessions in the past. These unions would typically be in more traditional sectors of the economy like manufacturing.

Second, a union that is an effective bargainer, even without their historical default, can expect to receive a large portion of the surplus generated from innovation. Such a union will be more willing to accept innovation.

Prediction 4.2 *A party with a strong claim on current surplus is more likely to accept innovation.*

The type of worker organisation referred to in Prediction 4.2 will provide a service required by the firms, for example a service in an area where there is a shortage of labour with those specialist skills.

Taken together, Predictions 4.1 and 4.2 suggest that measures of bargaining strength, such as union density, have an ambiguous sign on the probability of innovation. This is because the incentives to delay depends on the precise relationship between bargaining and innovation. This issue is discussed at more length in section 4.4.

Third, innovation reduces labour's ability to bargain in the future. The sort of change that might have this effect is the removal of a closed shop. This type of change can be expected to substantially reduce a union's bargaining power, increasing the incentive for labour to reject innovation.

Prediction 4.3 *The stronger the initial bargaining strength of a party facing an innovation that reduces their bargaining power, the more likely they are to reject innovation.*

Another example of such a change would be the introduction of a new technology that makes a particular group of workers redundant. For example, innovation like the introduction of new printing technology virtually removed the need for print type setters. A craft union is more likely to face a drastic innovation and, as a consequence, is more likely to oppose innovation than a more broadly-based employee organisation. The empirical estimates in this paper test this prediction, in particular with reference to craft-based unions.

Last, consider how a labour's bargaining power interacts with expected future surplus. If agreement reduces the future default payoffs of a party, delay is more likely when expected future surplus is lower. An example of this would be a union in an industry in decline or facing the introduction of new competition (reducing rents). On the other hand, if innovation reduces current bargaining power, a party is more likely to delay agreement when expected future surplus is larger.

Prediction 4.4 *A party with a strong historical default is more likely to delay when future surplus is expected to be low and when innovation reduces their default payoff. A party facing a drastic innovation that reduces their current bargaining potency is more likely to delay when future surplus is expected to be high.*

This prediction provides a refutable hypothesis that is exploited in the empirical estimation presented below. Essentially this prediction suggests that the effect on probability of innovation of higher future surplus (for example positive) is the opposite to the effect of lower future surplus (for example negative). It is inconsistent with the theory that both variables have a coefficient of the same sign, be it positive or negative. This is explored at greater length in section 4.4

4.4 Data and empirical models

The data used in this study are from the Australian Workplace Industrial Relations Survey 1995 (AWIRS 95).† The main survey sampled 2001 workplaces with over 20 employees covering all major ANZSIC divisions across all States and Territories. The main survey consisted of four questionnaires: the General Management Questionnaire completed by the most senior manager at the workplace; the Employee Relations Management Questionnaire targeted at the manager with the most day-to-day responsibility for employee relations at the workplace; the Union Delegate Questionnaire aimed at the senior delegate from the union with the most members at the workplace; and an Employee Survey Questionnaire, which was given to a randomly selected sample of employees at workplaces from the main survey. This thesis uses of the first three questionnaires, all of which were conducted by personal interview. Both the General Management and the Employee Relations Management Questionnaires have a sample of 2001, while the Union Delegate Questionnaire has a sample of 1086.

4.4.1 Model 1 - the probability of innovation

The first model is based on question BF1 from the General Manager in the main Questionnaire:

> which, if any, of the changes listed, happened at this workplace in the last 2 years? 1. Introduction of major new office technology (not just routine replacement); 2. Introduction of major new plant, machinery or equipment (not just routine replacement); 3. Major reorganisation of workplace structure (for example, changing the number of management levels, restructuring whole divisions/sections and so on); 4. Major changes to how non-managerial employees do their work (for example, changes in the range of tasks done, changes in the type of work done); 5. None of the above.

†The survey and the data is described in detail in Morehead et al (1997).

From this question a 0-1 dependent variable was constructed, termed 'organisational change'. If none of the four possible changes had occurred at the workplace, the dependent variable took on the value of zero. The index was assigned a value of 1 if there had been some form of innovation at the workplace. This organisational change index was used as the dependent variable in a probit estimation.

In addition, each of the four possible changes, namely the introduction of new technology, the introduction of machinery or equipment, a major reorganisation of the workplace and major changes to work, were used to construct four separate variables. Again, if the change was made the dependent variable took on the value of 1, and 0 if the change was not made. These four variables were each used as dependent variables in probit estimations. This model is similar to the studies of Brooks and Crockett (1993), Nunes et al (1993) and Drago and Wooden (1994), all of whom used Australian data, and the work of Machin and Wadhwani (1991) who used British data.

Table 4.1, in Appendix A, presents the number and proportions of workplaces that implemented different innovations in the areas of: technical change; plant or equipment; a reorganisation of the workplace structure; a change in the work of nonmanagers; and organisational change, the composite variable described above. This table shows that most workplaces implemented a change of some sort, with 84 per cent of workplaces making at least one type of innovation. It follows that 16 per cent of workplaces did not make any of the four innovations. Changes relating to plant and equipment were least common (28 per cent) while 59 per cent of workplaces made a reorganisation of the workplace.

As a measure of how many different changes were made, the responses to the four specific changes were combined to give a number between 0, if no changes were implemented, up to 4 if all four possible changes occurred at a workplace in the two years prior. This index is used as the dependent variable for an ordered probit.[†]

[†]These variables differ from Nunes et al (1993) in several ways. In particular, this paper does not use product change, job redesign or the implementation of an incentive/bonus scheme, semi-autonomous work groups or quality circles as dependent variables. This approach was decided upon because it was thought that these variables do not necessarily capture the essence of an

Table 4.2 shows the number of workplaces that implemented zero, one, two, three and all four possible changes.

4.4.2 Model 2 - attitudes towards innovation

The second model examines the attitudes of labour to the major change that occurred at their workplace. Question BF11 asked the general manager:

> how would you rate the reaction of each of these groups to the introduction of (the most significant change)? Union delegates; Full time union officials; Employees directly affected by the change; Employees generally at this workplace; First-line supervisors; Management at this workplace: 1 Strongly resistant; 2 Resistant; 3 Neutral; 4 In favour; 5 Strongly in favour.

The responses for: union delegates; full-time union officials; employees directly affected; and employees generally were compiled into an index from 1 to 5 for each group, with 1 representing a strongly resistant response through to 5 representing the relevant party being strongly in favour of the change. Each of these variables are used as dependent variables in ordered probit estimations. Tables 4.3, 4.4, 4.5 and 4.6 in Appendix A shows the attitudes to the major change at their workplace for each group. Notably, union delegates were far less positive than the other groups about the innovation. For example, 67 per cent of union delegates were strongly resistant to the main change at their workplace, whereas this figure was only 8, 5 and 2 per cent for full-time union officials, employees directly affected and general employees respectively.

innovation in the theoretical model. An innovation in the theory involves a change that cannot be unilaterally reversed by the employee or by the union and that involves the worker(s)/union losing some bargaining power in the future. It was decided that these characteristics were less applicable to these omitted variables, hence they were not included in this study.

4.4.3 Model 3 - delay of innovation

Finally, the dependent variables of the third model relates to question BF13 in the General Management Questionnaire:

> What, if any, significant efficiency change would you like to make at this workplace but cannot?

Those workplaces that wished to make changes that were irrelevant as far as the theory is concerned, such as wanting to change government policy, were excluded from the estimates below. In all 1130 workplaces out of a possible 1921 wished to implement some change relevant to the theory but could not. First, this demonstrates that delay is empirically important. Table 4.7 in Appendix A shows the reasons why the change could not be implemented. The reasons given by the general managers support the assumptions made in the theoretical model, namely that firms face wealth constraints and that employees or unions have the ability to stall or veto change.

Given this information about the workplaces, two indices of delay are constructed. The first dependent variable equalled 0 if a workplace wanted to implement a change but could not do so and 1 if it did not have such a problem (it was not delayed). This variable is used as the dependent variable in a probit estimation. Second, from the two questions from the General Management Questionnaire discussed above, it is possible to categorise all workplaces into four groups: those who didn't innovate and did not want to; those who wanted to innovate but were prevented from doing so; those who did implement some changes but who still wished to do more; and those who innovated and did not wish to implement any additional changes. The sample was restricted to those wishing to innovate and an index was created for the last three categories. This index provides a direct measure of delay. The first group were workplaces that were prevented completely from implementing change. The second group of workplaces did implement some changes but wanted to do more. Finally, there was no delay of innovation at the last group. This 1,2,3 index is used as the dependent variable in an multinominal logit.

Again, as far as the author is aware this is the first time such an index has been used in an empirical model.

4.4.4 Independent variables

The theory suggests that the probability of delay is affected by the ability of a workplace to pay compensation, the bargaining power of employees or the union and the expected size of future surplus. The independent variables used in the empirical estimates relate to these factors. Several other variables, highlighted as potentially important by other theoretical models, are included as controls. The independent variables outlined in this subsection are used in each of the three models described above.

Prediction 4.1 suggests that a union with a strong historical bargaining position is more likely to delay innovation. Prediction 4.2 suggests that a union with strong bargaining power is more likely to accept innovation. The empirical model includes a union density variable, defined as the proportion of the total number of employees at a workplace who are members of a union. To the extent that union density measures the strength of a union's historical position, it will be negatively associated with the probability of innovation. On the other hand, if union density reflects current bargaining power it could be positively associated with the probability of change. A priori, the sign of union density is ambiguous.†

Prediction 4.3 suggests that a craft union is more likely to delay innovation than a broadly-based union. From the answers of the union delegate, it is known how many different types of workers (managers, para-professionals, trades people, labourers etc.) the main union in a workplace represents. This answer is constructed into a variable from 1 to 8, with the number referring to how many different types of

†In the literature the effect of unions on innovation is also ambiguous. Dowrick and Spencer (1994) showed that a union may wish to accept or reject innovation under different circumstances. Other models suggest that union activity can hinder investment (for example Grout 1984) or that it can be positively associated with innovation (Freeman and Medoff 1984 and Williamson 1983). Further, the incentive to develop new labour-saving capital may be enhanced if union activity has the effect of increasing labour costs. Thus, while in the short run union activity could be negatively correlated with innovation, this relationship could be positive in the long run.

workers the union represents. This number indicates how 'craft based' a union is or, alternatively, how narrowly defined its interests are.† Assuming that an innovation has a greater negative impact on a craft union than on a more broadly based union, the coefficient on this index should be positively correlated with innovation (and negatively correlated with delay).†

The number of unions present at the workplace could also indicate how narrowly defined the interests of unions are. However, the probability of innovation could be reduced if the presence of many unions in a workplace requires that the firm bargain with and compensate a greater number of interest groups.

Prediction 4.4 relates to the expected size of future surplus. According to the basic model, delay is more likely when future surplus is low, or when an industry is in decline. That is, the expected sign of the coefficient on the demand contracting variable is negative (more delay) and it is positive on the demand expanding variable (less delay). On the other hand, with the drastic innovation model, delay is more likely when expected future surplus is high, for example in an expanding industry: this suggests contracting demand is positively associated with innovation while there is a negative relationship between expanding demand and innovation. Although these predictions differ, it is notable that the theory suggests that if the demand expanding coefficient is positive (negative), the demand contracting coefficient is likely to be negative (positive).

In the empirical model, product demand is used as a proxy for surplus. Question BC8 asks 'Is the demand for your workplace's main product or service currently expanding, stable or contracting?' Responses to this question are used to create two dummy variables, one if demand is expanding and one if contracting. If a

†As an alternative specification, dummy variables were created for unions with a 'medium' diversity of interests who represented two or three employee groups and for unions with 'broad' interests who represented four or more worker types. The effect of these dummies was estimated, relative to 'craft' unions who represented only one occupational group. These results, not reported, were similar to the results discussed here.

†As the Union Delegate Questionnaire had a smaller number of responses than the General Management Questionnaire an additional estimation was calculated including this variable. The coefficient estimates for the craft union variable, however, are included in the table along with the other variables.

workplace's demand was expanding it is interpreted that expected future surplus is larger and if demand was contracting it is interpreted that future surplus is expected to be smaller.†

The estimates include three broad industry dummies.† In addition, the three industry dummies are interacted with the demand expanding and the demand contracting dummy variables. Thus for each industry grouping there are two additional dummies.† Using the demand contracting and demand expanding dummies, constrains the coefficients to be the same across all industries. Interacting the three industry dummy variables with the demand variables allows for more flexibility. Two specifications of each model are estimated. The first includes just the industry dummies. The second specification includes both the industry dummies and the demand-industry interaction variables.

From the theory, the probability of delay is increased if a workplace has limited access to funds in order to pay compensation. Both workplace and organisation size are included in the estimates on the assumption that larger bodies have greater access to external sources of finance.† The probability of innovation is expected to be positively related to both size measures. Likewise, an owner-operated dummy variable was included on the basis that such workplaces may have more limited

†Typically the introduction of competition to a government monopoly involves a redistribution of rents. This provides another possible empirical test of the theory presented above: a union facing the onset of competition and an innovation that removes their historical default position are more likely to delay, whereas, a union anticipating greater product market competition and a drastic innovation are more likely to accept change. This, of course, presumes that participation in the market is not dependent on adopting the innovation.

†Industry A includes ANZSIC industries in mining, manufacturing and construction. Industry B includes workplaces in accommodation, wholesale, retail and transport while Industry C includes business services, property services, education, health, community services, sports and recreation, personal services, the arts, other and several other minor categories. The default comparison industry group includes government administration and electricity, gas and water. Different industry specifications were tried and these only marginally altered the coefficients on the other independent variables on the other industry dummies. In particular, the Electricity, Gas and Water classification was shifted from the default to Industry A and government administration was included in Industry C with only a minor effect.

†In fact the main reason for collapsing the industry dummies is to create a manageable number of variables.

†Delay relates to the compensation required relative to the funds available. The compensation required for larger organisations is likely to be more than that needed by smaller workplaces, but it is assumed that this increase is outweighed by their improved access to finance.

access to external sources of finance.

The General Manager Questionnaire also provides information about the level of competition the workplace faces. The general manager was asked to rank competition level as intense, strong, moderate, some or limited. An index from 1 to 5 was generated from these responses and included in each of the estimations, 5 being the greater the level of competition.[†]

A workplace can be expected to face greater competitive pressure if it is either exporting or facing import competition. From the General Manager Questionnaire, a trade index was created with four discrete values between 0 and 3, the higher number reflecting either more import or export competition.[†]

A dummy variable was included for non-commercial workplaces.

Table 4.8 displayed in Appendix A shows the means and standard deviations of the independent variables used in the empirical analysis. Appendix B provides a detailed account of the data manipulations used in the estimations.

4.5 Results

The estimations were calculated using the STATA statistical software package. Marginal effects are reported for the probit estimates. The marginal effects are calculated as the change in probability for an infinitesimal change in each continuous variable and a discrete change in probability for dummy variables, evaluated at the sample means of the data.[†]

[†]See Tirole (1988) Chapter 10 for a discussion of the incentive to innovate for a monopolist as compared with a competitive firm. Further, Canton, de Groot and Nahuis (2000) and Dowrick and Spencer (1994) develop theoretical models in which greater product market competition increases the incentive to accept innovation. In Dorwick and Spencer (1994) a union is more likely to accept an innovation the higher the elasticity of demand in the product market. This is because a reduction in price is more likely to translate into higher sales and greater demand for labour.

[†]Using the typical import and export dummies separately was also estimated with little effect on the coefficient on the variables of interest so, for the sake of having a parsimonious model, the single index was adopted.

[†]Also see Greene (1997), Chapter 19.

4.5.1 Model 1 - the probability of innovation

The estimation results for Model 1 are shown in Tables 4.9-4.14 in Appendix A. The results in Table 4.9 show that organisation size is positively correlated with the probability that a workplace made some organisational change (significant at the 5 per cent level). The coefficient for organisational ~~change~~ size is also positive and significant for the estimates with technical change, reorganisation of the workplace and a change in work of non-managers. A workplace experiencing an increase in demand is 5 percentage points more likely to have innovated than a workplace that fac~~ing~~es stable demand, again significant at the one per cent level (Table 4.9). Also note, the marginal effect of the contracting demand dummy variable is negative but insignificant. A similar pattern emerges with all four specific innovation categories (Tables 4.10, 4.11, 4.12 and 4.13). This is consistent with the theoretical model in which the bargaining party loses its historical default when agreeing to innovation.

Returning to the organisational change dependent variable, while the level of competition was insignificant, the trade index was positive and significant at the one per cent level.[†] The number of unions is positively related to the probability of change while the coefficient for the union density variable was negative and insignificant. The craft union index, from the estimation with the smaller sample, is insignificant (Table 4.9). Somewhat similarly, there is no consistent pattern for the union variable estimates across the different specific innovations. For example, the number of unions is negatively correlated with the probability of technical change, whereas it is positively correlated with a reorganisation of the workplace. Further, union density is negatively correlated with the probability of technical change but it is positively correlated with a change in the work of nonmanagers. Although insignificant for every other dependent variable, the craft union index was positively correlated with a workplace reorganisation (Table 4.12), consistent with the theory.

The estimations that include the interaction terms between demand contracting and expanding and the industry groupings are displayed in the right hand columns

[†]The competition variable was positive and significant for technical change (Table 4.9).

of the respective tables. For example, consider the organisation change index presented in Table 4.9. The results of the estimations are robust to this altered specification: the size of the organisation and the number of unions at a workplace remain positively related to the probability of change at the 1 and 10 per cent levels of significance respectively. Similarly, the trade index is positive and significant, again at the 1 per cent level. The first notable feature of the coefficients on the expanding demand-industry interaction dummy variables is that are positive; ~~and~~ conversely, all of the contracting industry dummies are negative. Further, the demand expanding dummies for industry group A and industry group B are significant at the 5 per cent level. Viewed from the framework of the theory presented above, this is consistent with the same bargaining model applying across the different industries. Similar results were estimated using the specific innovations.

Finally, consider the ordered probit of the number of organisational changes implemented in a workplace. The key results discussed above hold. The workplace and organisation size coefficients are positive and significant, as is the trade index coefficient. The craft union index is positive and significant, indicating workplaces with more broadly-based unions were more likely to implement a greater number of innovations. The number of unions variable was also positive and significant. Once again, the demand expanding variable was positive and significant while the demand contracting variable was negative and insignificant. These results translated over to the estimates with the industry-demand interaction terms.

4.5.2 Model 2 - attitudes towards innovation

Tables 4.15, 4.16, 4.17 and 4.18 show the results of the ordered probit estimates for the attitudes of: union delegates: full-time union officials; employees directly affected by the innovation; and employees generally. Consider the estimates for employees directly affected by the change, presented in Table 4.17. The basic estimation specification, reported in the left hand columns, reveals that the coefficient for the owner-operated dummy was negative and significant (5 per cent), organisation size was negative and significant (1 per cent) and the coefficient on commercial workplaces was negative and significant at the 10 per cent level. The coefficients on the union density and the number of unions were negative and significant (at the 1 per cent level), while the craft union index was insignificant. Finally, as with Model 1 the demand expanding variable coefficient was positive and significant (at the 1 per cent level). The coefficient for the demand contracting dummy variable was negative but insignificant. For the estimation using the demand interactions, the coefficients on the demand expanding variable for industry A, B and C were all positive and significant (at the 10, 10 and 5 per cent level of significance respectively).

The estimation results for employees generally were broadly similar to those for employees directly affected by the change. The results for the union delegate and the full-time union official differed somewhat. For example, the union density variable was positive and significant for the full-time union official estimates (see Table ..16). However, the estimate results relating to the demand variables remained remarkably similar across all four groups. The demand expanding coefficient was positive and significant for two of the three variables: the demand contracting variable was negative and insignificant for two of the three estimation groups as well. The estimates with the demand-industry type interaction terms were again similar, particularly for the employees directly affected by the change and for employees generally.

4.5.3 Model 3 - delay of innovation

The probit estimates with the simple index of delay are reported in Table 4.19. For the basic specification, workplaces with contracting demand were 8 per cent more likely to experience delay than workplaces with stable demand (significant at the 5 per cent level). The coefficients for the number of unions, union density and on the commercial workplace dummy variable were negative and significant at the 1 per cent level. These results also held when the probit was estimated using the demand-industry interaction terms. Of the interaction terms, only the demand contracting dummy variable for industry A was significant (5 per cent), the coefficient showing that workplaces with contracting demand had a 14 per cent higher probability of delay (that is, not being able to implement some innovation).

The multinominal estimation results using the delay index are presented in tables 4.20 and 4.21.[†] For these estimates the base group are workplaces that were delayed and did not innovate. The second category are those workplaces that innovated to a degree but that were also prevented from implementing some change. The third category were those innovating workplaces that were not delayed at all. In the basic specification without the demand-industry interaction terms, shown in table .20, the first column relates to category 2 (partial innovation) relative to category 1 (no innovation due to delay). The coefficient on the demand expanding variable was positive and significant (10 per cent), as it was for organisation size (5 per cent level of significance) and the trade index (5 per cent). For category 3 (no delay) relative to category 1 displayed in the right hand columns, the coefficient on the owner-operated workplace dummy variable was positive and significant at the 10 per cent level, as was the organisation size variable. The demand expanding dummy variable was positive and significant (5 per cent level of significance), while the coefficient on the demand contracting variable was negative and significant (also at the 5 per cent level). Finally, the union density coefficient was negative and significant at the 1 per cent but the craft union variable was insignificant.

The results in Table 4.21 show that with the expanded specification the coefficients on organisation size, trade, the owner-operated dummy variable and union density remained the same in terms of sign, magnitude and significance as reported above. For category 2, as compared with the delayed category (group 1), both of the coefficients for industry A interacted with the demand dummies were negative and insignificant, while for industry B the coefficient on demand expanding was positive and significant (5 per cent) while the contracting demand dummy variable coefficient was negative and insignificant. Further, the demand expanding coefficient for industry C was positive and significant (10 per cent), while the demand contracting variable was negative and insignificant. For category 3, relative to the

[†]An ordered probit was also estimated with the index producing similar results.

delay-comparison group, the coefficients of the demand variables repeated the pattern observed in the other estimates: the contracting demand variable in industry A was negative and significant (10 per cent), demand expanding in industry B was positive and significant (1 per cent), as was the demand expanding dummy variable for industry C (at a 1 per cent level of significance).

4.5.4 Discussion

The data presented here examines the probability of innovation, the attitudes to reform and the factors relating to when a workplace wanted to innovate but was prevented from doing so. Overall, larger organisations were more likely to innovate and not to suffer delay than their smaller counterparts. This is consistent with the predictions of the theory. The effect of the union variables was somewhat mixed although union density was positively associated with negative attitudes towards innovation and negatively associated with a workplace not experiencing any delay. This supports Prediction 4.1 over Prediction 4.2.

A significant contribution of the analysis is that it provides a new interpretation for the effect of the demand expanding and contracting variables (Prediction 4.4). Other papers have not distinguished between the effect of increasing or decreasing demand (for example Nunes et al 1993). Although the incentive to delay depends on the type of innovation and the bargaining solution, a prediction from the theory is that if the sign of one of these dummies is positive (for example the demand expanding dummy), the dummy for the other variable is likely to be negative (the demand contracting dummy variable in this case). This result is a common finding in the empirical estimations presented above, and when it is not the case at least one of the variables is insignificant. These results lend support to the theory presented above.

Another new aspect of this empirical model is that it analyses the attitudes to innovation and directly assess the factors related to the delay of innovation. Further, this is the first study to assess the relationship between innovation and delay and how narrowly focused a union is, using the 'craft' variable (Prediction 4.3).

Although some results for the craft variable were positive and significant, the variable was insignificant on a majority of occasions. There are several possible reasons for this. First, the index relates to how many worker types a union represented rather than directly measuring whether a union is based around a craft or not. Second, most unions in the sample have a narrow focus: approximately 75 per cent of unions represent fewer than three worker groups. Third, the craft union index only relates to the main union in a workplace. Fourth, Dowrick and Spencer (1994) also predicted that industry-level unions were more likely to oppose innovation than enterprise-based unions. This characteristic is not accounted for in the data used. At this stage, further research is needed into this issue.

Of course, there are several caveats that need to be taken into account. First, even though the question about innovation relates to the two previous years, the data used here are a cross section. As a consequence, there is the possibility that a workplace may undertake significant innovation prior to the start of the sample period, after, or both. The implicit assumption is that every workplace becomes aware of the potential innovations at the same time (at the start of the sample period) and choose whether to implement the change immediately (within the two year window) or delay. This assumption would not be appropriate if, for example, workplaces in larger organisations are more aware of potential reforms than smaller workplaces.

Second, given the timing of the questions some of the independent variables may not be truly exogenous. For example, whether or not a workplace implemented an innovation may help determine whether demand is expanding or contracting.

Third, the organisation change index combines four different types of innovations together. It is not altogether obvious that this grouping is appropriate. By combining these innovations it is assumed that these different changes have the same effect on the bargaining power of the union/employees.

Fourth, on a related point, the theory makes some very particular assumptions that may not hold for some of the innovations in question. For example, the theory assumes some contractual incompleteness and that innovation affects the bargaining outcome.

4.6 Conclusions

This chapter examined three aspects of innovation and delay of innovation using the AWIRS 95 survey: first, the characteristics of workplace that implemented an innovation; second, the attitudes of unionists and employees of workplaces that implemented some change; and, third, a direct measure of delay in innovation derived from information concerning workplaces that were prevented from implementing a significant efficiency-enhancing change. As far as the author is aware, this is the first time either of the latter two aspects of innovation have been studied.

This study also provided an new empirical test of the theory of delays in bargaining with incomplete contracts presented in Chapter 3, albeit an indirect one. Considering the effect of innovation on the distribution of future surplus, the theory suggests that if the probability of innovation is positively correlated with higher future surplus, innovation should be negatively correlated with lower future surplus. This relationship is consistently borne out in the data for different specifications and across the three different models. The theory also suggests that workplaces that are financially constrained are also more likely to be delayed in their attempt to implement change. Variables indicating the size of the workplace and organisation, and possibly their access to financial funds, were consistently associated with higher rates of innovation and a lower probability of delay. The relationship between the union variables and innovation is mixed; the empirical results depended on both the specific innovation and the measure of union involvement. However, the theory suggests that more broadly-based unions are less likely to oppose innovation that unions with a narrow interest group, such as craft unions. Although there is some limited support for the notion that broad-based unions are associated with higher rates of innovation, this result was far from conclusive. The impact of craft unions remains area for future empirical work.

4.7 Appendix A

Table 4.1: Number and proportion of workplaces that implemented different innovations

Variable	Number and Proportion
Organisational change	1481 (0.84)
Technical change	793 (0.45)
Plant and equipment	494 (0.28)
Reorganisation	1040 (0.59)
Work of nonmanagers	828 (0.47)
Total	1763

Source: Australian Workplace Industrial Relations Survey 1995

Table 4.2: The number of reforms implemented by workplaces

Number of changes	Number of workplaces and proportion
0	312 (0.16)
1	494 (0.25)
2	624 (0.31)
3	385 (0.19)
4	186 (0.09)
Total	2001 (1.00)

Source: Australian Workplace Industrial Relations Survey 1995

Table 4.3: The attitudes of union delegates to the major innovation at a workplace

Attitude index	Number and Proportion
1	80 (0.67)
2	224 (0.19)
3	459 (0.38)
4	358 (0.30)
5	81 (0.07)
Total	1202 (1.00)

Source: Australian Workplace Industrial Relations Survey 1995

Table 4.4: The attitudes of full-time union officials to the major innovation at a workplace

Attitude index	Number and Proportion
1	87 (0.08)
2	178 (0.15)
3	565 (0.49)
4	270 (0.23)
5	59 (0.05)
Total	1159 (1.00)

Source: Australian Workplace Industrial Relations Survey 1995

Table 4.5: The attitudes of employees directly affected by the major innovation at a workplace

Attitude index	Number and Proportion
1	76 (0.05)
2	348 (0.21)
3	289 (0.17)
4	699 (0.42)
5	269 (0.16)
Total	1681 (1.00)

Source: Australian Workplace Industrial Relations Survey 1995

Table 4.6: The attitudes of employees generally to the major innovation at a workplace

Attitude index	Number and Proportion
1	31 (0.02)
2	236 (0.14)
3	405 (0.24)
4	794 (0.47)
5	218 (0.13)
Total	1684 (1.00)

Source: Australian Workplace Industrial Relations Survey 1995

Table 4.7: Reasons for workplaces failing to implement an innovation that enhances efficiency

Reason	Number and Proportion
Financial constraints	270 (0.24)
Union resistance	141 (0.12)
Employee resistance	90 (0.08)
Award/Enterprise agreement	139 (0.12)
Other	490 (0.43)
Total	1130 (1.00)

Source: Australian Workplace Industrial Relations Survey 1995

Table 4.8: Means and standard deviations of variables used in the empirical analysis

Variable	Mean	Standard deviation
Owner	0.148	0.355
Workplace size	196.955	369.068
Organisation size	5392.954	7505.756
Commercial workplace	0.283	0.451
Trade Index	0.423	0.746
Level of competition	3.026	0.875
Demand expanding	0.537	0.499
Demand contracting	0.113	0.316
Number of unions	1.886	1.813
Union density	0.462	0.338
Craft union index	1.443	1.693
Industry A	0.274	0.446
Industry B	0.226	0.419
Industry C	0.394	0.489
Industry D	0.106	0.308
*Industry A * expanding dv*	0.113	0.317
*Industry A * contracting dv*	0.051	0.219
*Industry B * expanding dv*	0.127	0.333
*Industry B * contracting dv*	0.024	0.153
*Industry C * expanding dv*	0.230	0.421
*Industry C * contracting dv*	0.029	0.168

Source: Australian Workplace Industrial Relations Survey 1995
*Industry A * expanding dv* is equal to the demand expanding dummy variable multiplied by the Industry A dummy variable. Likewise for Industries B and C.
*Industry A * contracting dv* is equal to the demand contracting dummy variable multiplied by the Industry A dummy variable. Likewise for Industries B and C.
Industry D is the default industry.

Table 4.9: Probit estimation results with organisational change as the dependent variable

	dF/dx	z	dF/dx	z
Owner [a]	0.021	0.85	0.021	0.86
Workplace size	1.78E-5	0.67	1.78E-5	0.67
Competition	0.015	1.56	0.016	1.63
Org size	4.12E-6***	3.07	3.98E-6***	2.97
Demand exp [a]	0.055***	2.94		
Demand cont [a]	-0.0219	-0.79		
No. of unions	0.011*	1.66	0.011*	1.65
Union density	-0.004	-0.13	-0.005	-0.16
Craft [ab]	0.012	1.60	0.012	1.58
Trade Index	0.039***	2.83	0.039***	2.87
Ind A [a]	-0.133***	-3.1	-0.162***	-3.37
Ind B [a]	-0.157***	-3.52	-0.228***	-4.29
Ind C [a]	-0.084	-2.38	-0.118***	-2.94
*Ind A * exp* [a]			0.024	0.71
*Ind A * cont* [a]			-0.019	-0.43
*Ind B * exp* [a]			0.081***	2.66
*Ind B * cont* [a]			-0.033	-0.57
*Ind C * exp* [a]			0.054**	1.96
*Ind C * cont* [a]			-0.058	-1.05
Comm [a]	0.006	0.26	0.006	0.23
obs. P	0.843		0.843	
pred. P	0.854		0.855	
N	1763		1763	
Log likelihood	-732.216		70.95	
Prob > chi2	0		0	
Pseudo R2	0.043		0.046	

* significant at 10 per cent, ** significant at 5 per cent, *** significant at 1 per cent
[b] Coeffs from estimations with 978 obs and log likelihoods of -332.6 and -330.6
[a] dF/dx is for a discrete change of the dummy variable from 0 to 1.

Table 4.10: Probit estimation results with technical change as the dependent variable

	dF/dx	z	dF/dx	z
Owner [a]	-0.028	-0.77	-0.029	-0.79
Workplace size	5.97E-5	-1.44	-6.0E-5	-1.45
Competition	0.038***	2.62	0.039***	2.68
Org. size	5.25E-6***	2.94	4.93E-6***	2.74
Demand exp [a]	0.060**	2.29		
Demand cont [a]	-0.040	-0.96		
No. of unions	-5.67E-4*	0.07	-4.1E-4	-0.05
Union density	-0.074*	-1.75	-0.077*	-1.81
Craft [ab]	0.015	1.22	0.013	1.05
Trade Index	0.032*	1.67	0.034*	1.74
Ind A [a]	-0.177***	-3.61	-0.226***	-4.08
Ind B [a]	-0.802	-1.63	-0.144**	-2.42
Ind C [a]	-0.076*	-1.81	-0.081	-1.64
*Ind A * exp* [a]			0.071	1.36
*Ind A * cont* [a]			0.025	-0.37
*Ind B * exp* [a]			0.139*	2.53
*Ind B * cont* [a]			-0.172*	-1.90
*Ind C * exp* [a]			0.016	0.40
*Ind C * cont* [a]			-0.092	-1.23
Comm [a]	0.093***	2.89	0.094***	-2.71
obs. P	0.453		0.453	
pred. P	0.451		0.451	
N	1763		1763	
Log likelihood	-1176.42		-1170.89	
Prob > chi2	0		0	
Pseudo R2	0.031		0.036	

* significant at 10 per cent, ** significant at 5 per cent, *** significant at 1 per cent
[b] Coefficients from estimations with 978 observations and log likelihood of -645.1 and -636.7 respectively
[a] dF/dx is for a discrete change of the dummy variable from 0 to 1.

Table 4.11: Probit estimate results with plant, equipment or machinery changes as the dependent variable

	dF/dx	z	dF/dx	z
Owner [a]	-0.070**	-2.25	-0.072**	-2.27
Workplace size	3.83E-5	1.09	3.82E-5	1.08
Competition	0.003	0.21	0.003	0.26
Org. size	-2.43E-6	-1.48	-2.4E-6	-1.46
Demand exp [a]	0.058**	2.43		
Demand cont [a]	0.002	0.07		
No. of unions	0.010	1.27	0.010	1.28
Union density	0.088**	2.30	0.088**	2.32
Craft [ab]	0.006	0.55	0.007	0.66
Trade Index	0.052***	3.16	0.051***	3.11
Ind A [a]	0.313***	6.00	0.268***	4.68
Ind B [a]	0.188***	3.62	0.141**	2.28
Ind C [a]	0.129***	2.93	0.089*	1.76
*Ind A * exp* [a]			0.081*	1.80
*Ind A * cont* [a]			-0.026	-0.49
*Ind B * exp* [a]			0.058	1.12
*Ind B * cont* [a]			0.058	0.70
*Ind C * exp* [a]			0.060	1.50
*Ind C * cont* [a]			-8.89E-4	-0.01
Comm [a]	-0.033	-1.02	-0.035	-1.08
obs. P	0.289		0.289	
pred. P	0.277		0.277	
N	1763		1763	
Log likelihood	-994.620		-993.587	
Prob > chi2	0		0	
Pseudo R2	0.061		0.062	

* significant at 10 per cent, ** significant at 5 per cent, *** significant at 1 per cent
[b] Coefficients from estimations with 978 observations and log likelihood of -556.1 and -552.1 respectively
[a] dF/dx is for a discrete change of the dummy variable from 0 to 1.

Table 4.12: Probit estimation results with reorganisation of workplace as dependent variable

	dF/dx	z	dF/dx	z
Owner [a]	0.106***	3.02	0.108***	3.06
Workplace size	1.32E-4***	3.29	1.32E-4***	3.29
Competition	0.007	0.51	0.008	0.54
Org. size	3.82E-6**	2.13	3.68E-6**	2.05
Demand exp [a]	0.050*	1.92		
Demand cont [a]	-0.011	-0.27		
No. of unions	0.020**	2.25	0.020**	2.26
Union density	0.022	0.52	0.020	0.48
Craft [ab]	0.024**	2.04	0.023**	2.02
Trade Index	0.022	1.15	0.021	1.14
Ind A [a]	-0.272***	-5.21	-0.279***	-4.78
Ind B [a]	-0.301***	-5.81	-0.337***	-5.45
Ind C [a]	-0.180***	-4.01	-0.231***	-4.50
*Ind A * exp* [a]			-0.011	-0.23
*Ind A * cont* [a]			-0.011	-0.18
*Ind B * exp* [a]			0.069	1.32
*Ind B * cont* [a]			-0.070	-0.78
*Ind C * exp* [a]			0.089**	2.2
*Ind C * cont* [a]			-0.031	-0.42
Comm [a]	0.005	0.15	0.004	0.11
obs. P	0.587		0.587	
pred. P	0.593		0.593	
N	1763		1763	
Log likelihood	-1137.074		-1134.443	
Prob > chi2	0		0	
Pseudo R2	0.049		0.051	

* significant at 10 per cent, ** significant at 5 per cent, *** significant at 1 per cent
[b] Coefficients from estimations with 978 observations and log likelihood of -613.3 and -611.4 respectively
[a] dF/dx is for a discrete change of the dummy variable from 0 to 1.

Table 4.13: Probit estimation results with change in the work of nonmanager as dependent variable

	dF/dx	z	dF/dx	z
Owner [a]	-0.010	-0.27	-0.010	-0.27
Workplace size	9.96E-5**	2.55	9.85E-5**	2.52
Competition	0.005	0.37	0.005	0.34
Org. size	3.71E-6**	2.07	3.7E-6**	2.06
Demand exp [a]	0.048*	1.81		
Demand cont [a]	-0.006	-0.14		
No. of unions	0.012	1.43	0.012	1.38
Union density	0.085**	2	0.086**	2.04
Craft [ab]	0.016	1.35	0.018	1.47
Trade Index	0.039**	2.04	0.038**	1.96
Ind A [a]	-0.149***	-3	-0.155***	-2.75
Ind B [a]	-0.166***	-3.38	-0.144**	-2.4
Ind C [a]	-0.100**	-2.37	-0.185***	-3.74
*Ind A * exp* [a]			0.004	0.09
*Ind A * cont* [a]			-0.039	-0.60
*Ind B * exp* [a]			-0.027	-0.49
*Ind B * cont* [a]			-0.111	-1.22
*Ind C * exp* [a]			0.138***	3.30
*Ind C * cont* [a]			0.056	0.73
Comm [a]	-0.018	-0.51	-0.020	-0.57
obs. P	0.475		0.475	
pred. P	0.475		0.475	
N	1763		1763	
Log likelihood	-1188.35		-1183.81	
Prob > chi2	0		0	
Pseudo R2	0.026		0.0295	

* significant at 10 per cent, ** significant at 5 per cent, *** significant at 1 per cent
[b] Coefficients from estimations with 978 observations and log likelihood of -662.8 and -659.8 respectively
[a] dF/dx is for a discrete change of the dummy variable from 0 to 1.

Table 4.14: Ordered probit estimation results with organisational change index as the dependent variable

	Coef.	z	Coef.	z
Owner	0.002	0.03	0.003	0.035
Competition	0.047	1.59	0.048	1.614
Workplace size	1.81E-4**	2.17	1.80E-4**	2.169
Demand exp	0.195***	3.56		
Demand cont	-0.055	-0.64		
Org. size	9.39E-6**	2.53	8.92E-6**	2.39
No. of unions	0.034*	1.90	0.034*	1.88
Union density	0.116	1.31	0.115	1.31
Craft [b]	0.055**	2.21	0.055**	2.21
Trade Index	0.136***	3.44	0.136***	3.42
Ind A	-0.281***	-2.68	-0.378***	-3.19
Ind B	-0.352***	-3.40	-0.474***	-3.72
Ind C	-0.214**	-2.44	-0.371***	-3.58
*Ind A * exp*			0.136	1.28
*Ind A * cont*			-0.058	-0.43
*Ind B * exp*			0.233**	2.02
*Ind B * cont*			-0.260	-1.37
*Ind C * exp*			0.264***	3.05
*Ind C * cont*			-0.073	-0.46
Comm	0.044	0.61	0.040	0.56
cut 1	-0.764		-0.889	
cut 2	0.031		-0.092	
cut 3	0.887		0.766	
cut 4	1.653		1.53	
N	1763		1763	
Log likelihood	-2652.8		-2649.5	
Prob > chi2	0		0	
Pseudo R2	0.017		0.018	

* significant at 10 per cent, ** significant at 5 per cent, *** significant at 1 per cent
[b] Coefficients from estimations with 978 observations and log likelihood of -1458.5 and -1455.5 respectively

Table 4.15: Ordered probit estimation results of attitudes of union delegate to most significant change

	Coef.	z	Coef.	z
Owner	-0.067	-0.64	-0.065	-0.62
Competition	-0.002	-0.05	-1.59E-4	-0.004
Workplace size	-3.2E-5	-0.30	-2.03E-5	-0.19
Demand exp	0.183***	2.58		
Demand cont	-0.089	-0.78		
Org. size	-6.14E-6	-1.38	-6.57E-6***	-1.47
No. of unions	-0.059***	-2.79	-0.061	-2.87
Union density	0.036	0.29	0.048	0.38
Craft [b]	-0.021	-0.79	-0.016	-0.62
Trade Index	-0.043	-0.79	-0.048	-0.90
Ind A	0.649***	4.92	0.641***	4.30
Ind B	0.528***	4.12	0.418**	2.46
Ind C	0.313***	3.08	0.162	1.31
*Ind A * exp*			0.047	0.35
*Ind A * cont*			-0.353**	-1.99
*Ind B * exp*			0.171	1.04
*Ind B * cont*			0.039	0.12
*Ind C * exp*			0.236**	2.15
*Ind C * cont*			0.115	0.54
Comm	0.031	0.35	0.021	0.24
cut 1	-1.28		-1.387	
cut 2	-0.395		-0.500	
cut 3	0.652		0.549	
cut 4	1.804		1.702	
N	1080		1080	
Log likelihood	-1488.2		-1487.66	
Prob > chi2	0		0	
Pseudo R2	0.018		0.018	

* significant at 10 per cent, ** significant at 5 per cent, *** significant at 1 per cent
[b] Coefficients from estimations with 864 observations and log likelihood of -1176.2 and -1172.5 respectively

Table 4.16: Ordered probit estimation results with attitudes of full time union official to most significant change as the dependent variable

	Coef.	z	Coef.	z
Owner	-0.138	-1.29	-0.127	-1.18
Competition	-0.025	-0.63	-0.021	-0.51
Workplace size	2.3E-5	0.21	2.86E-5	0.26
Demand exp	0.086	1.17		
Demand cont	-0.142	-1.19		
Org. size	-1.99E-6	-0.43	-1.42E-6	-0.31
No. of unions	-0.061***	-0.43	-0.061***	-2.81
Union density	0.322**	-2.84	0.321**	2.44
Craft [b]	0.40	1.43	0.039	1.39
Trade Index	0.047	2.45	0.043	0.78
Ind A	0.431***	0.85	0.408	2.65
Ind B	0.383***	3.16	0.271	1.5
Ind C	0.141	2.91	0.111	0.86
*Ind A * exp*			0.063	0.45
*Ind A * cont*			-0.205	-1.12
*Ind B * exp*			0.138	0.81
*Ind B * cont*			0.309	0.99
*Ind C * exp*			0.091	0.79
*Ind C * cont*		-1.04	-0.442**	-1.96
Comm	-0.094		-0.095	-1.05
cut 1	-1.313		-1.343	
cut 2	-0.584		-0.610	
cut 3	0.796		0.774	
cut 4	1.869		1.847	
N	1039		1039	
Log likelihood	-1339.2		-1339.2	
Prob > chi2	0		0	
Pseudo R2	0.021		0.021	

* significant at 10 per cent, ** significant at 5 per cent, *** significant at 1 per cent
[b] Coefficients from estimations with 777 observations and log likelihood of -1012.9 and -1009.0 respectively

Table 4.17: Ordered probit estimates with attitudes of employees directly affected by the most significant change

	Coef.	z	Coef.	z
Owner	-0.191**	-2.25	-0.196**	-2.30
Competition	0.028	0.81	0.028	0.84
Workplace size	-1.40E-4	-1.34	-1.34E-4	-1.29
Demand exp	0.213***	3.48		
Demand cont	-0.036	-0.37		
Org. size	-1.51E-5***	-3.73	-1.56E-5***	-3.83
No. of unions	-0.073***	-3.66	-0.073***	-3.69
Union density	-0.361***	-3.69	-0.354***	-3.62
Craft [b]	-0.011	-0.43	-0.010	-0.36
Trade Index	-0.022	-0.49	-0.022	-0.51
Ind A	0.521***	4.56	0.392***	3.01
Ind B	0.456***	4.04	0.293**	2.04
Ind C	0.304***	3.23	0.166	1.48
*Ind A * exp*			0.229*	1.93
*Ind A * cont*			-0.114	-0.74
*Ind B * exp*			0.256*	1.94
*Ind B * cont*			6.06E-4	0.003
*Ind C * exp*			0.208**	2.19
*Ind C * cont*			0.095	0.52
Comm	-0.154*	-1.95	-0.161	-2.04
cut 1	-1.761		-1.894	
cut 2	-0.643		-0.778	
cut 3	-0.151		-0.286	
cut 4	1.123		0.990	
N	1479		1479	
Log likelihood	-2020.0		-2019.9	
Prob > chi2	0		0	
Pseudo R2	0.040		0.040	

* significant at 10 per cent, ** significant at 5 per cent, *** significant at 1 per cent

[b] Coeffs from estimations with 862 obs and log likelihoods of -1192.5 and -1190.3.

Table 4.18: Ordered probit estimation results with attitudes of employees generally to the most significant change

	Coef.	z	Coef.	z
Owner	-0.105	-1.22	-0.110	-1.23
Competition	0.058*	1.72	0.060*	1.75
Workplace size	-7.72E-5	-0.74	-7.45E-5	-0.71
Demand exp	0.236***	3.83		
Demand cont	0.045	0.46		
Org. size	-1.81E-5***	-4.44	-1.86E-5***	-4.54
No. of unions	-0.049**	-2.45	-0.049**	-2.47
Union density	-0.356***	-3.61	-0.355***	-3.60
Craft [b]	0.009	0.34	0.009	0.33
Trade Index	-0.040	-0.90	-0.042	-0.95
Ind A	0.583***	5.07	0.466***	3.55
Ind B	0.574***	5.04	0.400***	2.77
Ind C	0.372***	3.93	0.177	1.57
*Ind A * exp*			0.186	1.55
*Ind A * cont*			-0.062	-0.40
*Ind B * exp*			0.276**	2.07
*Ind B * cont*			-0.033	-0.14
*Ind C * exp*			0.300***	3.13
*Ind C * cont*	-0.136	-1.71	0.097	0.53
Comm [a]	-0.136	-1.71	-0.145*	-1.82
cut 1	-1.903		-2.064	
cut 2	-0.759		-0.918	
cut 3	0.021		-0.138	
cut 4	1.505		1.348	
N	1482		1482	
Log likelihood	-1865.3		-1963.8	
Prob > chi2	0		0	
Pseudo R2	0.041		0.042	

* significant at 10 per cent, ** significant at 5 per cent, *** significant at 1 per cent
[b] Coefficients from estimations with 864 observations and log likelihood of -1105.7 and -1100.7 respectively

Table 4.19: Probit estimations results with delay/no delay as the dependent variable

	dF/dx	z	dF/dx	z
Owner [a]	0.041	1.13	0.041	1.13
Competition	0.005	0.34	0.005	0.37
Workplace size	1.14E-5	0.28	1.29E-5	0.31
Demand exp [a]	4.36E-3	0.16		
Demand cont [a]	-0.084**	-2.07		
Org. size	-1.76E-6	-0.95	-0.2E-5	-1.08
No. of unions	-0.024***	-2.66	-0.025***	-2.71
Union density	-0.173***	-4.01	-0.174***	-4.03
Craft [ab]	-0.006	-0.51	-0.005	-0.44
Trade Index	-0.027	-1.45	-0.028	-1.46
Ind A [a]	0.030	0.59	0.069	1.20
Ind B [a]	0.079	1.54	0.044	0.72
Ind C [a]	-0.047	-1.08	-0.058	-1.13
*Ind A * exp* [a]			-0.050	-1.01
*Ind A * cont* [a]			-0.144**	-2.39
*Ind B * exp* [a]			0.072	1.31
*Ind B * cont* [a]			-0.060	-0.69
*Ind C * exp* [a]			0.026	0.61
*Ind C * cont* [a]			-0.046	-0.58
Comm [a]	-0.096***	-2.73	-0.096***	-2.72
obs. P	0.401		0.401	
pred. P	0.396		0.396	
N	1692		1692	
Log likelihood	-1082.3		-1079.9	
Prob > chi2	0		0	
Pseudo R2	0.050		0.052	

* significant at 10 per cent, ** significant at 5 per cent, *** significant at 1 per cent
[b] Coefficients from estimations with 937 observations and log likelihood of -575.7 and -574.0 respectively
[a] dF/dx is for a discrete change of the dummy variable from 0 to 1.

Table 4.20: Multinomial logit estimation results with the index of delay as the dependent variable

	Coef. nref=2	z	Coef. nref=3	z
Owner	0.421	1.36	0.526*	1.68
Competition	0.144	1.42	0.160	1.52
Workplace size	-8.46E-5	-0.27	6.07E-5	0.18
Demand exp	0.398*	1.96	0.437**	2.07
Demand cont	-0.341	-1.29	-0.646**	-2.28
Org. size	3.28E-5**	2.26	2.67E-5*	1.75
No. of unions	0.113	1.62	-0.012	-0.16
Union density	-0.358	-1.12	-0.963***	-2.87
Craft [b]	0.150	1.52	0.109	1.05
Trade Index	0.359**	2.32	0.244	1.54
Ind A	-0.949**	-2.40	-0.821**	-1.99
Ind B	-0.809**	-2.02	-0.554	-1.33
Ind C	-0.417	-1.20	-0.688*	-1.88
Comm	0.025	0.10	-0.386	-1.39
Constant	1.450***	3.14	1.631***	3.38
N	1568			
Log likelihood	-1371.9			
Prob > chi2	0			
Pseudo R2	0.043			

The base case (nref=1) is workplaces who wished to innovate but could not
nref=2: workplaces that made some innovation but were prevented from doing all they wanted to
nref=3: workplaces that innovated and were not delayed at all.
* significant at 10 per cent, ** significant at 5 per cent, *** significant at 1 per cent
[b] Coeffs from estimations with 900 obs and log likelihood of -762.3

Table 4.21: Multinominal logit estimation results with the index of delay as the dependent variable with industry-demand interactions

	coef nref=2	z	coef nref=3	z
Owner	0.446	1.439	0.551*	1.75
Competition	0.145	1.415	0.167	1.57
Workplace size	-8.7E-5	-0.27	6.29E-5	0.19
Org. size	3.1E-5**	2.11	2.39E-5	1.55
No. of unions	0.111	1.59	-0.014	-0.19
Union density	-0.388	-1.21	-0.998***	-2.96
Craft [b]	0.155	1.55	0.117	0.27
Trade Index	0.366**	2.36	0.247*	1.55
Ind A	-1.009**	-2.27	-0.767**	-1.67
Ind B	-1.213***	-2.67	-1.13**	-2.40
Ind C	-0.642*	-1.66	-0.95	-2.31
*Ind A * exp*	-0.089	-0.24	-0.191	-0.50
*Ind A * cont*	-0.215	-0.51	-0.865*	-1.90
*Ind B * exp*	1.161**	2.44	1.434***	3.00
*Ind B * cont*	-0.659	-1.23	-0.622	-1.13
*Ind C * exp*	0.542*	1.69	0.625*	1.83
*Ind C * cont*	0.562	-1.21	-0.738	-1.39
Comm	0.028	0.11	0.386	-1.39
Constant	1.66***	3.71	1.838***	3.94
N	1568			
Log likelihood	-1364.32			
Prob > chi2	0.00			
Pseudo R2	0.048			

The base case (nref=1) is workplaces who wished to innovate but could not
nref=2: workplaces that made some innovation but were prevented from doing all they wanted to
nref=3: workplaces that innovated and were not delayed at all.
* significant at 10 per cent, ** significant at 5 per cent, *** significant at 1 per cent
[b] Coeffs from estimations with 978 obs and log likelihood of -759.5.

4.8 Appendix B: Data description and manipulations

This appendix details the questions of AWIRS used and the manipulations undertaken to create the variables in the estimations.

Ownership of the workplace

Questions: bb9. Details: If bb9=1 or 2 the owner DV=0; if bb9=3, 4 or 5 owner DV=1.

Workplace size

Questions: bb1. Details: workplace size=bb1

Organisation size

Questions: ba13, bb17. Details: If ba13=2, multi=0, if ba13=1, multi=1; osize=50 if bb17=1, osize=300 if bb17=2, osize=50 if bb17=1, osize=300 if bb17=2, osize=750 if bb17=3, osize=3000 if bb17=4, osize=7500 if bb17=5, osize=15000 if bb17=6, osize=20000 if bb17=7; then organisation size=multi*osize.

Commercial operation

Questions: ba6. Details: commercial=0 if ba6=1, commercial=1 if ba6=2.

Import competition

Questions: bc4. Details: import competition=1 if bc4=1, import competition=0 if bc4=2, import competition=0 if bc4=.

Export

Questions: bc3. Details: export=0 if bc3=1, export=1 if bc3=2, export=2 if bc3=3, export=0 if bc3=.

Traded sector index

Questions: ba4, ba3. Details: trade=0 if import competition=0 & export=0, trade=1 if import competition=1 & export=0, trade=1 if import competition=0 & export=1, trade=2 if import competition=0 & export=2, trade=2 if import competition=1 & export=1, trade=3 if import competition=1 & export=2.

Level of competition

Questions: bc6. Details: competition level=0 if bc6=5, competition level=1 if bc6=4, competition level=2 if bc6=3, competition level=3 if bc6=2, competition level=4 if bc6=1, competition level=3 if bc6=.

Demand expanding

Questions: bc8. Details: demand expanding=0 if bc8=2, demand expanding=0 if bc8=3, demand expanding=1 if bc8=1.

Demand contracting

Questions: bc8. Details: demand contracting=0 if bc8=2, demand contracting=0 if bc8=1, demand contracting=1 if bc8=3.

Number of unions

Questions: cn1. Details: number of unions=cn1.

Union coverage or density

Questions: cn6, a1, a3. Details: For each occupational group in cn6 (8 groups), the following proportions were used All employees (1) =1, Most employees (2) = 0.67 Some employees (3) = 0.33 None (4)= 0, if cn6=. then 0 allocated. These proportions were then multiplied with number of employees in each group given in a3. This number is divided by a1 to give union membership as a proportion of total employees at each workplace. This variable is constructed following the technique outlined in Morehead et al (1997) pp. 141-42, with the slight difference that they drop observations if over one half of the proportion of type of employees responses for a workplace are missing. This difference means that the union density variable used here is slightly lower than reported by Morehead et al (1997).

Craft union versus broad based union index

Questions: da7 Details: craft1=1 if da7a = 100 and 0 otherwise, craft2=1 if da7b=100 and 0 otherwise, craft3=1 if da7c = 100 and 0 otherwise, craft4=1 if da7d = 100 and 0 otherwise, craft5=1 if da7e = 100 and 0 otherwise, craft6=1 if da7f = 100 and 0 otherwise, craft7=1 if da7g = 100 and 0 otherwise and craft8=1 if da7h = 100 and 0 otherwise; craft = craft1 + craft2 + craft3 + craft4 + craft5 + craft6 + craft7 + craft8.

Industry dummies

Questions: bb6. Details: industry A=1 if (ANZSIC industries) bb6>=11 & bb6<=15, Industry A=1 if bb6>=21 & bb6 <=29, Industry A = 1 if bb6> = 41

& bb6 <=42; Industry B=1 if bb6=57, Industry B = 1 if bb6 >=45 & bb6<=47, Industry B = 1 if bb6>=51 & bb6 <=53, Industry B=1 if bb6>=61 & bb6< =67; Industry C=1 if bb6>=71 & bb6<=78; Industry C = 1 if bb6=84; Industry C = 1 if bb6>=86 & bb6< =87, Industry C = 1 if bb6>=91 & bb6<=95, Industry C=1 if bb6=96.

Industry dummy variables interacted with demand expanding and contracting variables

Questions: bb6, bc8. Details: Expanding Industry A = (Industry A) * (demand expanding); Contracting Industry A = (Industry A) * (demand contracting); Expanding Industry B = (Industry B) * (demand expanding); Contracting Industry B=(Industry B) * (demand contracting); Expanding Industry C=(Industry C) * (demand expanding); Contracting Industry C = (Industry C) * (demand contracting).

Innovation

Questions: bf1. Details: technical change=1 if bf1a=100, Technical change=0 if bf1a=0; new plant or equipment=1 if bf1b = 100, new plant or equipment=0 if bf1b = 0; reorganisation of workplace=1 if bf1c = 100, reorganisation of workplace=0 if bf1c = 0; change in work of nonmanagers=1 if bf1d = 100, change in work of nonmanagers = 0 if bf1d = 0; organisational change = 1 if bf1e = 0, organisational change = 0 if bf1e = 100; index of change = (technical change) + (new plant or equipment) + (reorganisation of workplace) + (change in work of nonmanagers).

Attitudes to reform

Questions: bf11. Details: Attitudes of union delegate = 1 if bf11a = 1, Attitudes of union delegate = 2 if bf11a = 2; Attitudes of union delegate = 3 if bf11a = 3, Attitudes of union delegate = 4 if bf11a = 4; Attitudes of union delegate = 5 if bf11a = 5; Attitudes of full time union official = 1 if bf11b = 1, Attitudes of full time union official = 2 if bf11b = 2, Attitudes of full time union official = 3 if bf11b =3, Attitudes of full time union official = 4 if bf11b = 4, Attitudes of full time union official = 5 if bf11b = 5; Attitudes of employees directly affected = 1 if bf11c = 1, Attitudes of employees directly affected = 2 if bf11c = 2, Attitudes of employees directly affected = 3 if bf11c = 3, Attitudes of employees directly affected = 4 if bf11c = 4, Attitudes of employees directly affected = 5 if bf11c = 5; Attitudes of employees generally = 1 if bf11d = 1, Attitudes of employees generally = 2 if bf11d = 2, Attitudes of employees generally = 3 if bf11d = 3, Attitudes of employees generally = 4 if bf11d = 4, Attitudes of employees generally = 5 if bf11d = 5.

Non reform (delay/no delay and index of delay)

Questions: bf13, bf1. Details: non reform=0 if bf13b1 = 100, non reform=0 if bf13b2 = 100, non reform=0 if bf13b4 = 100, non reform=0 if bf13b5 = 100, non reform=0 if bf13b6 = 100, non reform=0 if bf13b8 = 100, non reform=0 if bf13b9 = 100, non reform=0 if bf13b10 = 100, non reform=0 if bf13b11 = 100, non reform=0 if bf13b12 = 100, non reform=0 if bf13b13 = 100, non reform=0 if bf13b14 = 100, non reform=0 if bf13b15 = 100, non reform=0 if bf13b17 = 100, non reform=0 if bf13b18 = 100, non reform=0 if bf13b20 = 100, non reform=0 if bf13b21 = 100, non reform=0 if bf13b22 = 100, non reform=0 if bf13b24 = 100, non reform=0 if bf13b27 = 100, non reform=0 if bf13b28 = 100, non reform=0 if bf13b30 = 100, non reform=1 if bf13a = 2; Index of delay=1 if non reform=0 & bf1e = 100, Index of delay=2 if non reform=0 & bf1e = 0, and Index of delay = 3 if non reform = 1 & bf1e = 0.

CHAPTER 5

Hold-up and sequential specific investments

5.1 Introduction

Many projects prior to their commencement are nebulous and difficult to describe. For example, research and development projects often have vague objectives and speculative or uncertain outcomes; start-up firms are often based around intangible ideas. With joint projects this makes it difficult to write a complete contract specifying the tasks of each party, and the desired outcome. After some of the project has been completed, however, it begins to take shape. As a consequence, it may be only after the project is underway that something resembling a complete contract can be written.† That is, after some investment has been sunk the project becomes well defined, allowing contracting on subsequent investment to be possible. This raises the question for the investing parties: should all the investment be made prior to when contracting is feasible, or should one of the parties wait until more complete contracts can be written before committing to invest? In the model presented here we examine this issue by considering simultaneous and sequential (or Stackelberg-staged) investments.

The basic structure of the model is as follows. Two parties are required to invest in order to complete a project. Two distinct alternatives are possible. First, they can invest simultaneously at the start of the game. If they do so, both invest

†Neher (1999) makes the point that contracting becomes more feasible as a project progresses as more of the human capital is converted into physical assets.

prior to complete contracting being possible. After both investments are sunk the parties renegotiate and the payoffs are realised. Alternatively, one party can invest first while the other party waits. This first investment allows the project to take shape: as a result, contracting on the second investment becomes possible. At this stage, the parties will renegotiate and write a contract specifying the second party's investment. The final stage of investment will then occur, completing the project and allowing the parties to receive their payoffs.

Several important results arise from this simultaneous versus sequential investment model. First, the paper investigates the relative efficiency of the two alternative investment regimes. When the investments are independent the model identifies three basic trade-offs between the regimes:

- The sequential system enlarges (relative to simultaneous investments) delay costs by increasing the length of time before the project matures.
- The sequential system reduces the first player's incentive to invest, vis-a-vis the simultaneous system, because of the longer time between his investment and when the returns are realised.
- The sequential system improves the incentive for the second player to invest efficiently as they do not suffer hold-up, as they do with simultaneous investments.

The ultimate impact on total surplus is a combination of these trade-offs. We show that under different circumstances either timing regime can be the welfare-maximising method of investing. Moreover, despite the simplicity of the model, no simple relationship between the welfare effects of the two regimes exists as there is no restriction on how the three trade-offs mentioned above interact. The model is also extended in several ways, for example by considering these trade-offs when the two investments are complements or when they are substitutes. Similarly, we examine the relative efficiency of the two regimes when either investment is relatively important in terms of its contribution to overall surplus.

Second, the sequential regime can create trading possibilities that may not be feasible if the parties only have the option of investing simultaneously. For example, the second player may not be willing to invest simultaneously because the hold-up that occurs during the subsequent renegotiation may leave them with negative utility. On the other hand, sequential investment gives this player the opportunity to delay their investment until when contracts are complete. This encourages the seller to invest and allows trade to proceed. This result is similar to the results of other authors, for example Neher (1999) and Admati and Perry (1991), albeit in a different context.

Third, we show that the possibility of investing sequentially does not always improve welfare. As it turns out, the mere possibility of flexibility in the timing of investment can act as an additional form of hold-up. For want of a better expression we call this kind of hold-up 'follow-up'. This occurs when both parties should invest simultaneously at the start of the project in order to maximise surplus but there is an incentive for one party to wait until after the other player has sunk their effort before they follow-up with their own investment.† Consider the case when technology requires that one particular party must invest at the commencement of a project but that the other party can invest either at the same time or wait. The first party will anticipate that the second party will delay their investment - opt for the sequential regime - if it suits them. The first party will then adjust their investment accordingly. In the extreme this additional form of hold-up will prevent a potential surplus-enhancing project from proceeding. Similarly, if there is an advantage from investing second, and there is no clear party that must invest first, this timing hold-up could reduce the potential gains from trade. In this situation determining who invests first, be it by technology or by some other mechanism, can help the parties avoid some of the costs of follow-up. This suggests that having different types of parties trading with each other can be a way of overcoming this form of hold-up.

Fourth, as discussed above, the second player acting in self-interest may have

†'Follow-up' can occur in addition to the regular hold-up of investment.

the incentive to opt for the regime that does not maximise total welfare. The burden of this opportunism is typically borne by the other player. However, if such opportunism drives the first player's return below his outside option, the second player also bears some of the cost from the reduction in total surplus. Indeed, it can be the case that the second player is disadvantaged by her inability to commit to a particular timing schedule of investment.

The applications of this model are many and varied. It is applicable where: a project is poorly defined before a project begins, but better defined sometime after it has been commenced (or commitment is possible at that time); and when the parties investments are 'lumpy' in the sense that each party makes their total investment at one time. For example, two parties making a specific investment in a particular location can opt to invest jointly, or in a sequential Stackelberg fashion. Similarly, two firms or departments involved in a joint research project may be able to invest simultaneously and pool the results or, alternatively, invest one after the other. Even two researchers, like a theorist and an econometrician, writing a joint paper could work simultaneously and negotiate how the research should be published when the results are known. Alternatively, one of them, for example, the econometrician, could wait for the theorist to complete her model before renegotiating about his specific task and what should be done with the output.

This paper draws on several streams of literature. First, it extends the analysis of hold-up with simultaneous investment, for example Grossman and Hart (1986) and Hart and Moore (1988).[†] These models are structured so that investments are made prior to renegotiation. This set up is equivalent to the simultaneous investment regime in the model presented here. An alternative literature considers hold-up when investment in a project can be made in arbitrarily small amounts over a potentially infinite horizon. For example, Admati and Perry (1991) show how two parties can overcome the free-rider problem by financing a public good in stages. Neher (1999) considers staged financing of a project when contracts are incomplete.

[†]In a similar fashion to Che and Hausch (1999) and MacLeod and Malcomson (1993a), this paper considers a cooperative investment.

The model presented here compares the relative advantages of these two streams of literature.

In a similar manner to the model in this chapter, De Fraja (1999) considered the Stackelberg-type sequencing of investments in the presence of hold-up. However, his suggested solution to the hold-up problem is inapplicable to model presented here as his model required the first investment to be general. In contrast, our model assumes both players make specific investments.[†]

Pitchford and Snyder (1999) studied a related model in their application of the Coase theorem. In their paper one party can choose to invest in a particular location aware that in the next period another party will physically locate next to them, and that this party will incur an external cost related to its investment. Contracts are incomplete as the first party is unaware of the exact identity of the second party before they physically locate in the second period. The first party can opt to invest prior to the arrival of the second party or to delay their investment so as to renegotiate (with complete contracts) with the newcomer when they arrive in the second period. Their model differs from ours in several respects. First, they consider only negative externalities between the two parties, rather than a joint project or partnership. Second, in their model it is the first party with the decision regarding timing. Here, the second party has the right to decide on the timing of investment.

The paper is organised as follows. Section 5.2 outlines the assumptions and timing of the model. In this section we also describe the bargaining solution used. Section 5.3 explores hold-up (follow-up) when the two parties make discrete investments. Analogous results are derived in section 5.4 with continuous investments. Section 5.5 extends the model in several different ways to explore the relative advantage of each regime when: investments are complements and substitutes; one party's investment is relatively more important than the other; the parties are wealth constrained; and when there is a lack of commitment so that renegotiation can occur at

[†]De Fraja's (1999) solution to the hold-up problem required the first party to make a general investment then make a take-it-or-leave-it offer to the other party that included him paying for the specific investment. Given the first party is the residual claimant he will invest efficiently.

any time. Finally, section 5.6 concludes the paper. Some of the proofs are contained in the Appendix A.

5.2 The model

There is a potentially profitable relationship between a buyer and a seller.† Specifically, if the buyer and seller invest I_1 and I_2 respectively the two parties share surplus R. The exact relationship between the investments and surplus is discussed below.

5.2.1 Timing

The timing of investment is the focus of this paper. Two alternatives are considered. First, the players invest simultaneously. The timing of this system of simultaneous investment is shown in Figure 5.1. In this case, both parties invest at the same time, at time $t = 1$. At this stage, contracting on either investment is not possible; consequently renegotiation will occur after both investments are sunk. (The renegotiation process is discussed below.) Definition 5.1 reiterates this discussion.

Definition 5.1 *Simultaneous investment occurs when both parties invest at the same time, prior to renegotiation.*

Figure 5.2 outlines the timing of the alternative investment regime. In this regime the buyer invests I_1 at time $t = 1$ prior to when contracting is possible.† However, this investment by itself makes the contracting process possible, so having observed I_1 the two parties renegotiate and contract on I_2. It is only at this stage that the seller makes her investment I_2. This occurs at time $t = 2$. After both investments have been made, surplus is realised and the payoffs to each party are made. Definition 5.2 defines sequential investment.

†These parties could just as well be denoted as Party A and Party B.

†In the context of the incomplete contracts literature this time can be thought of as the ex ante period.

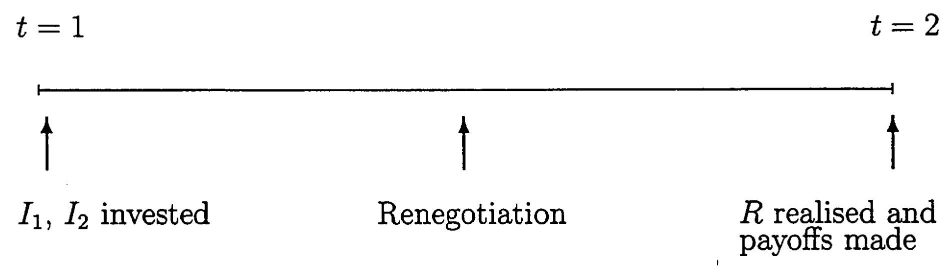

Figure 5.1: Simultaneous investment

Definition 5.2 *Sequential investment occurs when one party (the buyer) invests at time $t = 1$, while the other party (the seller) waits and invests at time $t = 2$.*

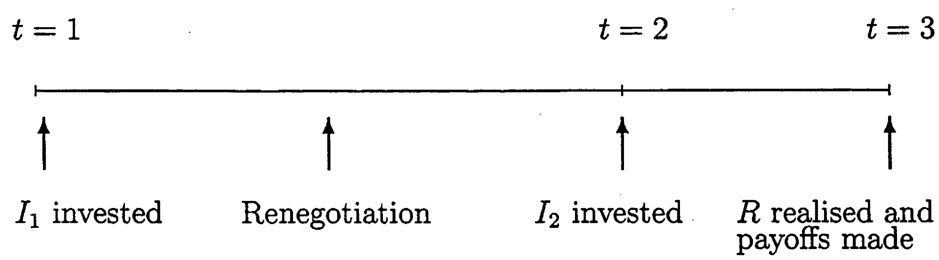

Figure 5.2: Sequential investment

5.2.2 Assumptions

As noted above, the investments of the buyer and seller (I_1 and I_2) combine together to generate surplus R. The investments of both parties are sunk and completely specific to the relationship in that they are worth zero outside the relationship. R is only available at the completion of the project. This is summarised in Assumption 5.1.

Assumption 5.1 *The buyer can make investment I_1 and the seller can invest I_2. Total surplus R is a function of I_1 and I_2: $R(I_1, I_2)$. Once invested both I_1 and I_2 are sunk and specific to the relationship.*

Although there is complete and symmetric information between the trading parties, the investments are unverifiable ex ante. However, as discussed above, once the buyer's investment has been sunk the project becomes tangible allowing subsequent investment to be verifiable. On the contrary, the surplus generated by the project is always unverifiable. As a result, contracts can be written on investments ex post (after the first period) but surplus is never contractible.[†] This prevents the parties writing surplus sharing agreements. These points are summarised in Assumption 5.2 and 5.3 and Remark 5.1.

Assumption 5.2 *Prior to the investment of I_1 both I_1 and I_2 are unverifiable, hence non-contractible.*

Assumption 5.3 *Surplus $R(I_1, I_2)$ is unverifiable.*

Remark 5.1 *Surplus sharing agreements are not feasible.*

As in Hart and Moore (1988) and MacLeod and Malcomson (1993a), the two parties cannot vertically integrate to overcome their hold-up problem. This could be due to specialisation, for example. If the parties could vertically integrate, as noted by Williamson (1983), they could overcome hold-up and investment would be efficient. Assumption 5.4 outlines this point.

[†]With no uncertainty there is a direct relationship between the level of investment and total surplus - a contract on investment effectively acts as an explicit contract on surplus. As a result, provided that the parties can write a contract on investment the first-best effort level (at that point in time) can be obtained. For example, consider when the parties cannot contract on surplus. A contract could specify the first-best level of investment for a player in return for a fixed payment. This payment would not be made, however, if the level of investment were observed at any other level. Consequently, this contract will ensure that this player invests efficiently. The other player could be subject to a similar contract. Alternatively, the second player could be made the residual claimant of the project. As the residual claimant they will receive the full marginal return from any investment, giving them an incentive to invest efficiently.

Assumption 5.4 *The two parties cannot vertically integrate.*

Finally, both the parties discount future returns and costs with a constant discount factor δ, as stated in Assumption 5.5.

Assumption 5.5 *Both parties discount future costs and returns with the discount factor δ per period, where $\delta \in (0, 1]$.*

The model adopts a reduced form bargaining solution, similar to one used by Chiu (1998), Neher (1999) and Hart and Moore (1994).† During renegotiation the final distribution of surplus is a combination of two factors. First, the distribution depends on the relative bargaining strengths of the two parties. For simplicity it is assumed that the parties have equal bargaining power.†

Assumption 5.6 *Both parties have equal bargaining power.*

Second, a party's outside option only affects the distribution of surplus if it is binding.

Assumption 5.7 *An outside option only affects the distribution of surplus if it is binding.*

Thus, if the buyer and seller have outside options of b_1 and b_2 respectively and the two parties are negotiating over surplus $R > b_1 + b_2$ the distribution will be:

$$\{\frac{1}{2}R, \frac{1}{2}R\} \text{ if } b_1 \leq \frac{1}{2}R \text{ and } b_2 \leq \frac{1}{2}R \tag{5.1}$$

$$\{b_1, R - b_1\} \text{ if } b_1 > \frac{1}{2}R; \text{ or} \tag{5.2}$$

†This bargaining solution is based on the alternating offers model with outside options of Shaked and Sutton (1984). Also see Osborne and Rubinstein (1990) and Muthoo (1999).

†The relative bargaining strengths of the parties are encapsulated in Chiu (1998) by α and $(1-\alpha)$, so that the first party receives α of the surplus. Here $\alpha = \frac{1}{2}$. These bargaining strengths depend on exogenous characteristics of the negotiating parties, for example their rate of time preference or their expectation of a breakdown in bargaining. As usual, sunk costs do not affect the distribution of surplus at renegotiation.

$$\{R - b_2, b_2\} \text{ if } b_2 > \frac{1}{2}R \tag{5.3}$$

where the first element is the surplus received by the buyer and the second element is the surplus received by the seller.

Typically, the choice of an inside or outside option bargaining solution dramatically affects the outcome of hold-up models.† Here we have adopted an outside option model, on the basis that a party must sever the specific relationship in order to take up the alternative. This is appropriate if a party must choose between investing in the specific relationship or investing in alternative trading possibility. Consequently the threat of adopting the alternative is only credible if it is binding, justifying the use of the outside option bargaining solution. It should be noted, however, that the choice of an outside option model here is not crucial. Rather, many of the results would remain if an alternative (inside) bargaining solution were used, suggesting that the results obtained here are robust.

5.3 Discrete-choice investment

This section explores the hold-up problem when the parties make discrete investments. Assume the buyer and the seller can make discrete investments of $I_1 = \{0, f_1\}$ and $I_2 = \{0, f_2\}$ respectively. The surplus generated will be equal to R if both f_1 and f_2 are invested and zero otherwise. Further, the buyer has an outside option of b_1 that he could receive trading elsewhere. However, the buyer forfeits this outside option by entering into the specific relationship with the seller. As noted above, this could occur if the buyer must choose between investing in the specific relationship and making an investment necessary for trade with another party.† Similarly, the seller's outside option b_2 is also inconsistent with investing in the specific relationship with the buyer. Trade between the buyer and seller is efficient; that is, $\delta^2 R - \delta f_2 - f_1 > b_1 + b_2$.† Assumption 5.8 summarises this

†See for example Chiu (1998) and De Meza and Lockwood (1998).

†This alternative could be a general or a specific investment.

†This assumption means that trade is efficient with both simultaneous and sequential investment as it follows from $\delta^2 R - \delta f_2 - f_1 > b_1 + b_2$ (the relevant condition for when investment is

discussion.

Assumption 5.8 *The buyer can make investment* $I_1 = \{0, f_1\}$ *and the seller can make investment* $I_2 = \{0, f_2\}$. *If* $I_1 = f_1$ *and* $I_2 = f_2$ *surplus* R *is available to the two parties. The buyer's outside option* b_1 *is inconsistent with* $I_1 = f_1$. *The seller's outside option* b_2 *is also inconsistent with* $I_2 = f_2$. *Further,* $b_1 + b_2 < \delta^2 R - \delta f_2 - f_1$.

First consider the outcome when the parties invest simultaneously. After investing f_1 and f_2, the parties will renegotiate over surplus R. In this case, the parties will distribute surplus equally.† Provided there is investment, the returns to the buyer and seller respectively are:

$$\frac{1}{2}\delta R - f_1; \tag{5.4}$$

and

$$\frac{1}{2}\delta R - f_2. \tag{5.5}$$

When only the simultaneous investment regime is available the buyer will anticipate a return of $\frac{1}{2}\delta R - f_1$ from within the relationship. Consequently, the buyer will opt into the investment relationship provided

$$\frac{1}{2}\delta R - f_1 \geq b_1. \tag{5.6}$$

The buyer will opt not to enter the relationship if

$$\frac{1}{2}\delta R - f_1 < b_1. \tag{5.7}$$

This is an example of the standard hold-up problem that arises with incomplete contracts. If contracting were complete, given overall surplus is increased within the specific relationship, the parties could contract on f_1 and ensure that the buyer

sequential) that $\delta R - f_2 - f_1 > b_1 + b_2$ (the relevant condition for simultaneous investment).

†Note, as both parties have invested in the specific relationship they have forfeited they outside options.

receive surplus at least as great as b_1. The same reasoning applies to the seller. If $\frac{1}{2}\delta R - f_2 \geq b_2$ the seller will opt into the relationship. Conversely, if $\frac{1}{2}\delta R - f_2 < b_2$ the seller will anticipate the hold-up problem and opt not to invest, reducing total surplus.†

Now consider when the parties can only invest sequentially. In this case the two parties will renegotiate after the buyer has sunk his investment but prior to the seller investing f_2.† From the bargaining solution outlined by equations 5.1, 5.2 and 5.3, when $b_2 \leq \frac{1}{2}(\delta^2 R - \delta f_2)$ and $b_1 \leq \frac{1}{2}(\delta^2 R - \delta f_2) - f_1$ the return of the buyer and seller, valued at $t = 1$, will be:

$$\frac{1}{2}(\delta^2 R - \delta f_2) - f_1; \tag{5.8}$$

and

$$\frac{1}{2}(\delta^2 R - \delta f_2). \tag{5.9}$$

The important element here is the treatment of the buyer and the seller in the renegotiation process. As the buyer has sunk their investment, f_1 does not affect the distribution of surplus. The seller, on the other hand, has not made her investment. Her investment f_2, as a consequence, is considered as part of net surplus the parties bargain over. In this sense, the seller avoids being held-up with sequential investment.

At this point we turn our attention to the situation when both regimes are possible. As noted in the literature, having the option of sequential investment can improve welfare. To see this consider the case when the buyer's outside option is never binding ($b_1 < \frac{1}{2}(\delta^2 R - \delta f_2) - f_1$): this ensures that the buyer will opt into the relationship regardless as to whether investments are simultaneous or sequential.

†As noted below, up-front compensation may have limited success overcoming the hold-up problem, as it must somehow be able to tie the party to the specific relationship by ensuring that they do not invest in any alternatives: this may not be possible with incomplete contracts. If the parties cannot contract on f_1 and f_2 they may not be able to contract on their alternative investment options.

†Although the seller still has her outside option at this stage, if this option were binding she would have maximised her surplus by taking this option immediately at the beginning of the game.

Further, assume $\frac{1}{2}(\delta^2 R - \delta f_2) > b_2 > \frac{1}{2}\delta R - f_2$.[†] As the seller's outside option b_2 exceeds her return if investments are simultaneous ($b_2 > \frac{1}{2}\delta R - f_2$) she would not enter the relationship if investments could only be made simultaneously. However the sequential regime may create an environment that helps facilitate trade between the parties. The seller will receive a payoff of $\frac{1}{2}(\delta^2 R - \delta f_2)$, valued at time $t = 1$, as the parties renegotiate after the buyer has invested but before the seller has done so. As noted above, this allows the seller to avoid being held-up: the extra surplus afforded the seller with sequential investment encourages her to invest where she would not otherwise done so. This discussion is summarised in Result 5.1.

Result 5.1 *When $b_1 < \frac{1}{2}(\delta^2 R - \delta f_2) - f_1$ and $\frac{1}{2}(\delta^2 R - \delta f_2) > b_2 > \frac{1}{2}\delta R - f_2$ sequential investment allows trade to occur that would not be feasible with only simultaneous system available.*

Proof. The proof follows from the discussion above and is omitted. □

This result mirrors much of the existing literature on the staging of investments with incomplete contracts. For example, Neher (1999) examined financing an entrepreneur overtime in stages rather than funding the entire project up-front. In his model the bargaining power of the financier (vis-a-vis the entrepreneur) is enhanced by the quantity of accumulated physical assets.[†] Consequently, as the project matures the financier has additional protection from hold-up. The possibility of funding in stages allows projects to proceed that would otherwise not be feasible. In the model presented here, on the other hand, it is assumed that as the project matures contracting becomes possible. If a party can delay their investment until this point in time they can avoid being held up. If the costs of hold-up are sufficiently great as compared with a party's outside opportunities the sequential regime provides scope for trade that may not have otherwise existed.

[†]If $b_2 > \frac{1}{2}(\delta^2 R - \delta f_2)$ the seller will opt out of the relationship immediately and pursue her outside option. She will receive a payoff of b_2, valued at time $t = 1$, from doing so. If she waits one period for the buyer to invest she will receive b_2 in renegotiation, but this will be only valued at δb_2 at time $t = 1$. Below we discuss the case where $b_2 > \frac{1}{2}(\delta^2 R - \delta f_2)$ and $\delta = 1$.

[†]Physical assets increase the liquidation value of the firm. This enhances the financier's outside option and, as a result, her claim on surplus.

Further to this, Neher found that staged financing allowed all profitable projects to proceed when $\delta = 1$. In the model presented here, if $\delta = 1$ the sequential regime increases the number of projects that will be financed. However, unlike in Neher (1999) not all profitable projects will proceed. Consider the outcome of the model when $\delta = 1$. Given that $b_1 < \frac{1}{2}(\delta^2 R - \delta f_2) - f_1 = \frac{1}{2}(R - f_2) - f_1$ the buyer will enter into the specific relationship regardless of regime, as noted above. Unlike in Result 5.1, the seller will be willing to invest in the relationship when her outside option is binding with both regimes. Assume that $b_2 > \frac{1}{2}(\delta^2 R - \delta f_2) = \frac{1}{2}(R - f_2)$. With sequential investment the seller will receive a payoff of b_2 during renegotiation - a payoff identical to her outside option valued at time $t = 1$. Additional trade occurs here that would not have done so if only the simultaneous regime were available or if $\delta < 1$. To show that not all profitable projects proceed when $\delta = 1$ assume that $b_1 > \frac{1}{2}(\delta^2 R - \delta f_2) - f_1 = \frac{1}{2}(R - f_2) - f_1$. If the buyer invests he will forfeit his outside option. With sequential investment he will end up with a lower payoff than if he had opted out of the relationship immediately. As a consequence, he will not invest in the relationship. This discussion is summarised in a corollary to Result 5.1.

Corollary 5.1 *When $b_1 < \frac{1}{2}(\delta^2 R - \delta f_2) - f_1$, $b_2 > \frac{1}{2}\delta R - f_2$ and $\delta = 1$ sequential investment allows for trade to occur that would not be feasible otherwise, increasing total surplus.*

Now we consider the case when $\frac{1}{2}\delta R - f_1 \geq b_1$ and $\frac{1}{2}\delta R - f_2 \geq b_2$. Given this, both parties would enter into the investment relationship if the simultaneous investment regime were the only option available. It is evident that simultaneous investment always produces greater surplus than sequential investment.† Nevertheless, the seller will act to maximise her own surplus and not to maximise total surplus. As a result, the seller will opt for the sequential regime if:

$$\frac{1}{2}(\delta^2 R - \delta f_2) > \frac{1}{2}\delta R - f_2 \tag{5.10}$$

†With discrete investments f_1 and f_2 are unchanged between both regimes. The only effect of a sequential regime is that it further delays the receipt of surplus one additional period from the start of the project. Consequently, if $\delta < 1$ the sequential regime produces a smaller ex ante return.

despite the fact that total surplus is reduced. Herein lies a potential hold-up problem - the seller will opportunistically opt for sequential investments even though surplus is maximised with simultaneous investment. To distinguish the inefficient timing of investment from the standard hold-up problem we call this practice 'follow-up'. This discussion is summarised in Result 5.2.

Result 5.2 *Given that $\frac{\delta}{2}R - f_1 \geq b_1$ and $\frac{\delta}{2}R - f_2 \geq b_2$, if the seller has the choice of whether to invest simultaneously or sequentially and $\frac{1}{2}(\delta^2 R - \delta f_2) > \frac{\delta}{2}R - f_2$ they will opt for the sequential regime, reducing total surplus.*

Proof. The proof follows from the discussion above and is omitted. □

This analysis brings to light another important implication not previously noted in the literature. Unlike most of the literature that has focused on how investing over many periods can allow parties to overcome the hold-up problem, it is shown here that the option of staggering investments can be detrimental to overall welfare.†

Now consider the effect of the sequential regime on the buyer's incentive to invest. Sequential investment puts the buyer at a disadvantage as his sequential payoff is necessarily less than his simultaneous payoff. From equations 5.4 and 5.8, $\frac{1}{2}(\delta^2 R - \delta f_2) - f_1 < \frac{1}{2}\delta R - f_1$. The buyer will be willing to enter into the specific relationship, despite the inevitable follow-up, if

$$\frac{1}{2}(\delta^2 R - \delta f_2) - f_1 \geq b_1. \tag{5.11}$$

On the other hand, if

$$\frac{1}{2}(\delta^2 R - \delta f_2) - f_1 < b_1 \tag{5.12}$$

the buyer will not be willing to enter. In this case, the follow-up problem is sufficiently great that the buyer's outside option is more attractive than entering into

†In the bargaining literature it has been known for some time that the addition of extra potential bargaining periods can reduce welfare. For example, Fudenberg and Tirole (1983) showed that the addition of extra period in a bargaining game with asymmetric information did not necessarily increase welfare for a bargaining game with only one potential bargaining period.

the relationship. As the buyer gives up his outside option by investing in the relationship he will require some compensation for doing so.† This mechanism, however, also requires that the parties can write a contract that precludes trade with other parties. Otherwise, after the compensation payment has been made, the buyer will opt out of the relationship.† Consequently, if a compensation payment cannot be made, due to wealth constraints or the non-transferability of utility, or if a contract precluding trade with another party is not verifiable, the follow-up problem will prevent a surplus enhancing trade from occurring altogether.

If the buyer's return from simultaneous investments exceeds his outside option but the sequential payoff did not, the seller would be better off if they could commit to invest simultaneously. If the seller could guarantee she would invest simultaneously the buyer would opt into the relationship, and both parties would be better off. When the seller cannot commit, the buyer will opt out of the relationship and the seller will suffer as trade between the parties will not occur. Result 5.3 summarises the case when compensation is not possible.†

Result 5.3 *If* $\frac{1}{2}\delta R - f_1 > b_1 > \frac{1}{2}(\delta^2 R - \delta f_2) - f_1$ *and* $\frac{1}{2}(\delta^2 R - \delta f_2) > \frac{1}{2}\delta R - f_2 > b_2$ *the surplus of the seller is reduced by having the option of a sequential regime of investment.*

Proof. The proof follows from the discussion above and is omitted. □

This is a similar result to Grout (1984) who argued that a union would be better off if it could commit not to opportunistically renegotiate after the firm has sunk its investment..

Up until this point it has been assumed that the seller has the option to adopt the sequential regime. What happens if either of the individuals can be the party

†The minimum compensation payment required would be equal to the difference between the returns to the buyer outside and inside the relationship, that is $b_1 - \{\frac{1}{2}(\delta^2 R - \delta f_2) - f_1\}$.

†Fixed payments do not affect marginal incentives.

†Suppose for a moment that compensation is feasible. Even then, the seller may be forced to share in the lower total surplus through her compensation payment to the buyer. If the seller prefers the sequential regime the buyer will require a minimum compensation payment of $b_1 - \{\frac{1}{2}(\delta^2 R - \delta f_2) - f_1\}$. The sequential return to the seller of $\{\frac{1}{2}(\delta^2 R - \delta f_2) - \text{compensation}\}$ may be less than her simultaneous payoff of $\frac{1}{2}\delta R - f_2$.

that invests first? It follows in this situation that either agent could also delay and choose to invest after contracts are complete. To investigate this assume the players are identical, so that $f_1 = f_2 = f$.† Further, assume that an investment by either individual would allow contracting to be feasible. If $\frac{1}{2}(\delta^2 R - \delta f) > \frac{\delta}{2}R - f$, both individuals would prefer to invest second.† Let us consider this case in more detail.

First, consider when there are just two potential investment periods in which the project can be completed and $[\frac{1}{2}(\delta^2 R - \delta f) - f] < 0$. In this case neither party will be willing to invest first. Moreover, as noted above, a contract on the timing of investments coupled with some up-front compensation is unlikely to resolve the problem.† Given the non-verifiability of investment a contract written on the timing of investment is unenforceable. Consequently, after the compensation payment has been made the recipient can simply trigger renegotiation again without fear of sanction. As a result, trade is unlikely to proceed in this case. Adding additional periods will not change this outcome.

Second, consider when the payoff for the individual who invests at $t = 1$ with sequential investments is positive: $[\frac{1}{2}(\delta^2 R - \delta f) - f] > 0$. To explore the strategies the players will adopt initially consider when there are exactly two periods remaining in which the project can be completed. The choice for each player is then to invest immediately at $t = 1$ or to wait and invest in the final period at time $t = 2$. As surplus from simultaneous investments is greater than the outside option, if the game reaches $t = 2$ both agents would invest if they had not previously done so. The normal form of this game is illustrated in Figure 5.3. In the figure I represents investing at $t = 1$ and II waiting and investing at $t = 2$. The payoff for the buyer is written in the top of each box in the matrix and the seller's at the bottom.

As

$$\frac{1}{2}(\delta^2 R - \delta f) > \frac{\delta}{2}R - f \tag{5.13}$$

†Also assume $b_1 = b_2 = 0$ for simplicity.

†When $\frac{1}{2}(\delta^2 R - \delta f) < \frac{\delta}{2}R - f$ the return from simultaneous investment exceeds the sequential payoff and both parties will invest at $t = 1$.

†The minimum compensation needed would be $-[\frac{1}{2}(\delta^2 R - \delta f) - f]$.

		Seller	
		I	II
Buyer	I	$\frac{\delta}{2}R - f$, $\frac{\delta}{2}R - f$	$\frac{1}{2}(\delta^2 R - \delta f) - f$, $\frac{1}{2}(\delta^2 R - \delta f)$
	II	$\frac{1}{2}(\delta^2 R - \delta f)$, $\frac{1}{2}(\delta^2 R - \delta f) - f$	$\delta(\frac{\delta}{2}R - f)$, $\delta(\frac{\delta}{2}R - f)$

Figure 5.3: Normal form for two period game

and

$$\delta(\frac{\delta}{2}R - f) > \frac{1}{2}(\delta^2 R - \delta f) - f \tag{5.14}$$

both players have a dominant strategy of delaying and investing at time $t = 2$. This is a version of prisoners' dilemma: surplus is maximised if both players invest simultaneously at $t = 1$, as that avoids the additional costs of delay, but the only Nash Equilibrium in this game is that each player will delay investing.

This artifact of the equilibrium arises as a result of the short time horizon. Now consider the case when there are three potential investment periods.[†]

Figure 5.4 illustrates the normal form game of the investment decision for both parties when there are three potential investment periods. The choice of each player initially is to invest immediately at $t = 1$ or to wait. If both players opt to invest

[†]Note, as above a maximum of two periods is needed to complete the project.

		Seller	
		I	II
Buyer	I	$\frac{\delta}{2}R - f$, $\frac{\delta}{2}R - f$	$\frac{1}{2}(\delta^2 R - \delta f) - f$, $\frac{1}{2}(\delta^2 R - \delta f)$
	II	$\frac{1}{2}(\delta^2 R - \delta f)$, $\frac{1}{2}(\delta^2 R - \delta f) - f$	$\delta^2(\frac{\delta}{2}R - f)$, $\delta^2(\frac{\delta}{2}R - f)$

Figure 5.4: Normal form for three period game

at $t = 1$ the project is completed in the first period and the payoffs are unchanged from the two-period horizon game. Similarly, if the buyer invests at $t = 1$ and the seller does not she will invest at $t = 2$ with probability equal to 1. The payoffs are unchanged from above, as they are if the buyer initially does not invest but the seller does. The only payoff that is altered is when both players opt to not invest at $t = 1$. When both players delay making an investment they proceed to the next period in which they are once again in a two-period horizon game. From above, the equilibrium in this two-period horizon game is that both players wait until the last period to invest. Consequently, the payoff in the three-period horizon game when both parties do not invest at $t = 1$ is the two-period payoff discounted for the extra period - that is, $\delta^2(\frac{\delta}{2}R - f)$. Provided

$$\delta^2(\frac{\delta}{2}R - f) > \frac{\delta}{2}(\delta R - f) - f \tag{5.15}$$

the dominant strategy remains to not invest at $t = 1$ for both players.

As more potential trading periods are added a similar adjustment of the payoffs continues. Figure 5.5 shows the normal form of the game with n potential bargaining periods.

		Seller	
		I	II
Buyer	I	$\frac{\delta}{2}R - f$, $\frac{\delta}{2}R - f$	$\frac{1}{2}(\delta^2 R - \delta f) - f$, $\frac{1}{2}(\delta^2 R - \delta f)$
	II	$\frac{1}{2}(\delta^2 R - \delta f)$, $\frac{1}{2}(\delta^2 R - \delta f) - f$	$\delta^n(\frac{\delta}{2}R - f)$, $\delta^n(\frac{\delta}{2}R - f)$

Figure 5.5: Normal form for n period game

At some point, say when the potential horizon has n periods, the payoff from not investing when the other player also does not invest becomes less than choosing to invest immediately. This occurs when

$$\delta^n(\frac{\delta}{2}R - f) < \frac{1}{2}(\delta^2 R - \delta f) - f < \delta^{n-1}(\frac{\delta}{2}R - f). \tag{5.16}$$

When the potential bargaining horizon is n periods there is no longer a dominant strategy for each player: each player will play a mixed strategy between investing immediately and waiting. The intuition is that when there is a long potential time horizon the players know that stalling until the end of the potential horizon is of little benefit as there is a sufficiently large number of periods that the payoff from waiting that long is relatively small. This provides an incentive to invest immediately. However, there is also a potential dividend from waiting on the chance that the other party invests immediately. The players are in a coordination game: each party wants the project to go ahead immediately but both investors would prefer to follow rather than lead. Also note that the game with $n+1$ potential investing periods may return to a prisoners' dilemma game. This arises because the coordination game with n periods is the outcome of waiting in the first of the $n+1$ periods. The payoff of this coordination game might be higher than $\frac{1}{2}(\delta^2 R - \delta f) - f$ which again creates a dominant strategy to wait. The game could chaotically switch between a prisoners' dilemma and a coordination game as periods are added.†

Two points are important here. First, if both parties have the opportunity to wait until after the other has invested, strategic behaviour can reduce total surplus. Second, if for technical reasons, as assumed above, that one player (the buyer) must invest at the start of the project, the potentially damaging coordination game regarding which party is to invest first is avoided. This suggests technical differences in the individuals that determine which of the parties must invest at the beginning of the project may help overcome some of the problems generated by the timing of investments and follow-up.

The issue of which party must invest first could be resolved naturally when the parties have differing outside options. Again assume that the investment costs and outside options are f_i and b_i for $i = 1, 2$, as outlined in Assumption 5.8. However, now assume that there is no specified order of investments (that is, either party can invest first to start the project). If $b_1 < [\frac{1}{2}(\delta^2 R - \delta f_2) - f_1]$, the buyer will be willing to enter the relationship regardless of which regime eventuates. Further, assume that

†A numerical example is contained in the Appendix A.

if the seller's cost of investment (f_2) or her outside option (b_2) is sufficiently high as to ensure that $\frac{\delta}{2}(\delta R - f_2) > b_2 > \frac{1}{2}\delta R - f_2$. In this case the seller would never invest first. She would be willing, however, to contract with the buyer after he has made his investment. Once again the option of sequential investments improves welfare - it allows for a trade opportunity that would not otherwise occur. The differing opportunity costs of the parties make it clear which party is to invest at $t = 1$: the party with the smallest investment cost (both direct and indirect) should invest first. This prediction accords with what is observed with venture capital projects. It is often the case that the financier, who is required to invest in production or marketing for example, waits until the venture capitalist, the party with the smaller opportunity cost, has already made their investment and the project is underway and better defined. Sequencing of investment in this case affords the financier the protection from hold-up needed to encourage participation.[†]

This section examined how the timing of investments can act as a potential source of hold-up. It has been shown that if a party can choose to invest prior to or after renegotiation the other party can be held-up by the timing of investment. This reduces the incentive for that party to invest and, in the extreme, prevents surplus enhancing transactions from taking place.[†] When there is an advantage of investing after the other party has sunk their investment (a follower advantage), the two parties may vie to invest second. We discuss how this problem can be overcome if the two parties are different, either technically or in terms of their outside options. The model is sufficiently flexible, however, to also be able to show the potential benefits of sequencing investment. Sequencing allows contracts to become complete: this protects the party investing second from being held-up, and consequently encourages investment by that party. Here, we have assumed that

[†]Differing discount factors between the two parties may also help to resolve which party should invest first. In this case more patient player may be willing to invest first. The second player with the lower discount factor, is consequently afforded the benefits of investing a period closer to the receipt of surplus.

[†]Of course, we have only outlined several cases in the discussion and the three results above. Other outcomes are possible. For example, if the buyer will only enter the relationship when investments are simultaneous, but the seller will only enter with the sequential regime, the two parties will forfeit the profitable trading opportunity.

the level of investment by each player is discrete and hence fixed if they decide to invest. In the next section we show how the above discussion applies in the case when investments are continuous.

5.4 Continuous investments

This section extends the discrete-choice model by allowing both investments to be continuous. As before total surplus is a function of both investments, however, now $R(I_1, I_2)$ is two times differentiable, non-decreasing in both variables and concave; that is $R_i' = \partial R(I_1, I_2)/\partial I_i \geq 0$, $R_{ii}'' = \partial^2 R(I_1, I_2)/\partial I_i^2 \leq 0$ for $i = 1, 2$ and $R_{11}'' R_{22}'' - (R_{12})^2 \geq 0$, as summarised by Assumption 5.9.

Assumption 5.9 $R_i' = \partial R(I_1, I_2)/\partial I_i \geq 0$, $R_{ii}'' = \partial^2 R(I_1, I_2)/\partial I_i^2 \leq 0$ *for* $i = 1, 2$ *and* $R_{11}'' R_{22}'' - (R_{12})^2 \geq 0$ *where* $R_{12} = \partial^2 R(I_1, I_2)/\partial I_1 \partial I_2$.

Assumption 5.9 will apply for the rest of the paper, unless explicitly stated otherwise. Further, we assume that $b_1 = b_2 = 0$ and that it is profitable for both to trade with each other, that is $\delta^2 R - \delta f_2 - f_1 > b_1 + b_2$.[†]

5.4.1 The relative advantage of sequencing investments

In this section we will consider four different possibilities: (1) when investment is simultaneous and contracts are complete; (2) when investment is simultaneous and contracts are incomplete; (3) when investment is sequential and contracts are complete; and (4) sequential investment when contracts are incomplete. The real emphasis here is comparing the relative efficiency of (2) and (4).

Simultaneous investment with no renegotiation

Assume that investment is contractible. In this case the first-best levels of investment are obtainable. If investments are made simultaneously the two parties

[†]We discuss non-zero outside options below.

will maximise

$$\max_{I_1,I_2} \delta R(I_1, I_2) - I_2 - I_1. \tag{5.17}$$

Surplus is discounted because the return from investment take one period in which to mature. The first order conditions for this problem are:

$$R_1' = 1/\delta; \tag{5.18}$$

and

$$R_2' = 1/\delta. \tag{5.19}$$

Assumption 5.9 guarantees there is a unique solution for both I_1 and I_2. Let the first best level of investment be I_1^* and I_2^*.

Simultaneous investment with renegotiation

Second, when investments are made simultaneously but contracts are incomplete both parties know that renegotiation will occur so they adjust their investments from the first-best level accordingly. The buyer chooses I_1 in order to maximise

$$\max_{I_1} \frac{\delta}{2} R(I_1, I_2) - I_1. \tag{5.20}$$

Here, the returns are discounted by δ because they are only available after one period. Renegotiation occurs after both investments have been sunk. From the bargaining solution outlined by equations 5.1, 5.2 and 5.3 each party anticipates receiving one half of the surplus. The first order condition for the buyer is

$$R_1' = \frac{2}{\delta}. \tag{5.21}$$

The seller faces a similar decision choosing her level of I_2. She will set I_2 to maximise

$$\max_{I_2} \frac{\delta}{2} R(I_1, I_2) - I_2, \tag{5.22}$$

which yields the first order condition of

$$R_2' = \frac{2}{\delta}. \tag{5.23}$$

Let the buyer's and seller's choices when investments are set simultaneously and renegotiation occurs to be $\widehat{I}_1$ and $\widehat{I}_2$ respectively. These values solve system of equations 5.20 and 5.22. The solutions are unique because of Assumption 5.9.

Sequential investment with complete contracts (no renegotiation)

Alternatively, if investments are made sequentially, the buyer will invest I_1 in the first period and the seller will invest I_2 in the second period. As contracts are complete renegotiation will never occur. Both investments will be set so as to maximise

$$\max_{I_1, I_2} \delta^2 R(I_1, I_2) - \delta I_2 - I_1. \tag{5.24}$$

The first-best first order conditions are:

$$\delta^2 R_1' = 1; \tag{5.25}$$

and

$$\delta R_2' = 1 \tag{5.26}$$

so that $R_1' = 1/\delta^2$ and $R_2' = 1/\delta$. Again, Assumption 5.9 ensures a unique solution for both investments. Let the first best level of investment in this case be I_1^{**} and I_2^{**}.

Sequential investment with incomplete contracts (renegotiation)

The final case is when the investments are made sequentially. The buyer invests I_1 at time $t = 1$. Following renegotiation, at time $t = 2$ the seller chooses I_2. In this case the buyer sets I_1 to maximise

$$\max_{I_1} \frac{\delta}{2}[\delta R(I_1, I_2) - I_2] - I_1. \tag{5.27}$$

The first order condition for this problem is

$$R_1' = \frac{2}{\delta^2}. \tag{5.28}$$

The seller, who sets her investment level after observing I_1 and renegotiating with the buyer will maximise

$$\max_{I_1} \frac{\delta}{2}[\delta R(I_1, I_2) - I_2]. \tag{5.29}$$

The first order condition for this maximisation problem is

$$R_2' = \frac{1}{\delta}. \tag{5.30}$$

Let the buyer's and the seller's levels of investment be $\widetilde{I}_1$ and $\widetilde{I}_2$. These values are the solution to the system of equations 5.28 and 5.30. The solutions are unique because of Assumption 5.9.

5.4.2 Simultaneous versus sequential regimes and total welfare

As it turns out very little can be said about the trade off between simultaneous and sequential investments when functions are general and contracts are incomplete. To explore the issue further first assume that the two investments have no influence on the marginal productivity of each other. That is, $R_{12} = 0$. This is stated in the following assumption.

Assumption 5.10 $R_{12}'' = 0$.

Remark 5.2 *If $R_{12}'' = 0$ it follows that $R = f_1(I_1) + f_2(I_2)$, where $f_i' > 0$ and $f_i'' \leq 0$ for $i = 1, 2$.*

$R_{12}'' = 0$ could arise when an investment by the buyer increases his benefit from trade whereas investment by the seller reduces her costs. Although they do not affect one another, each investment increases the potential surplus available to be split upon renegotiation. A similar assumption is made by Hart and Moore (1988).

In this framework three separate effects can be isolated that, when combined, give the relative advantage of either investment system. First, consider the costs of delay. Let the total surplus ex ante with simultaneous investment be S_2 and the total surplus ex ante when investment is sequential be S_4.† For two fixed levels of $\overline{I}_1$ and $\overline{I}_2$

$$S_2 = \delta R(\overline{I}_1, \overline{I}_2) - \overline{I}_1 - \overline{I}_2 > \delta^2 R(\overline{I}_1, \overline{I}_2) - \overline{I}_1 - \delta \overline{I}_2 = S_4. \tag{5.31}$$

As sequential investment delays the payoff an extra period, the surplus from simultaneous investment is greater than with sequential investments when I_1 and I_2 are fixed: the costs of delay always favour simultaneous investment. Further, the relative payoff of simultaneous investments is increasing as the players become more impatient. This effect is summarised below.

Effect 5.1 *The costs of delay reduce the surplus generated by sequential investment relative to the surplus with simultaneous investments.*

Second, consider the investment levels generated from each system. Examining the first order conditions 5.21 and 5.28, $\widehat{R}_1' = \frac{2}{\delta} \leq \widetilde{R}_1' = \frac{2}{\delta^2}$. From the assumption of concavity and monotonicity of R:

$$\widehat{I}_1 > \widetilde{I}_1. \tag{5.32}$$

The sequential investment regime delays the collection of returns to the buyer: this reduces the incentive for the buyer to invest.†

Effect 5.2 *Relative to the sequential regime, the simultaneous investment regime increases the incentive for the buyer to invest in I_1.*

†Both S_2 and S_4 relate to when contracts are incomplete.

†Note that both $\widehat{I}_1$ and $\widetilde{I}_1$ are below the first-best level. With simultaneous investments $\widehat{R}_1' = 2/\delta > R_1' = 1/\delta$, meaning that $\widehat{I}_1 < I_1^*$. Similarly, with sequential investment, $\widetilde{R}_1' = 2/\delta^2 > R_1' = 1/\delta^2$, meaning that $\widetilde{I}_1 < I_1^{**}$.

For the seller the relative incentives to invest with simultaneous and sequential investments are given by equations 5.23 and 5.30. Again, because of Assumption 5.9,

$$\widehat{I}_2 < \widetilde{I}_2. \tag{5.33}$$

With simultaneous investment the seller is held-up, as is the buyer. With sequential investment, however, the seller invests after renegotiation, thus avoiding any hold-up problems. In fact, the sequential investment level chosen by the seller equals the first best level, so that $\widetilde{I}_2 = I_2^{**}$ - this is the advantage of the sequential regime over simultaneous investment. Effect 5.3 summarises this discussion.

Effect 5.3 *The sequential investment regime increases I_2 to its first-best level.*

Effect 5.2 states that the simultaneous regime increases I_1. Effect 5.3 suggests that the sequential regime increases I_2. To assess the impact of an increase in either investment on total welfare, isolated from the costs of delay, consider S_2 relative to an augmented S_4, termed U_4, that has the same discount structure as the simultaneous system. U_4 ignores the additional discounting of R and of I_2 that occurs because of the additional period. In this case:

$$S_2 = \delta f_1(\widehat{I}_1) - \widehat{I}_1 + \delta f_2(\widehat{I}_2) - \widehat{I}_2. \tag{5.34}$$

where the level of investments are determined by equations 5.21 and 5.23. Similarly, using 5.28 and 5.30

$$U_4 = \delta f_1(\widetilde{I}_1) - \widetilde{I}_1 + \delta f_2(\widetilde{I}_2) - \widetilde{I}_2. \tag{5.35}$$

The relative incentives to invest for the seller and buyer are summarised in the following lemma.

Lemma 5.1 $\delta f_1(\widetilde{I}_1) - \widetilde{I}_1 < \delta f_1(\widehat{I}_1) - \widehat{I}_1,$ *and* $\delta f_2(\widetilde{I}_2) - \widetilde{I}_2 > \delta f_2(\widehat{I}_2) - \widehat{I}_2.$

Proof. See Appendix A. □

Lemma 5.1 indicates that increasing I_1 towards its first-best level always increases the surplus it generates. The same argument applies to I_2. As a consequence of Lemma 5.1, we can say that the surplus generated by I_1 is greater with the simultaneous regime. Similarly, the surplus generated by I_2 is greater with the sequential regime.

In terms of total surplus, the ultimate trade off between simultaneous and sequential systems depends on these three effects: delaying incurred from delayed returns favour simultaneous investments; delayed returns also amplify hold-up arising with sequential system and reduce the incentive for the buyer to invest, favouring the simultaneous system; and, finally, the sequential system increases the incentive for the seller to invest, increasing her contribution to total surplus. Two of these effects work in favour of the simultaneous system and one works in favour of the sequential system. Result 5.4 summarises this discussion.

Result 5.4 *There are three factors that affect the total surplus generated by the simultaneous system relative to the total surplus that will be generated by the sequential system.*

Proof. The proof follows from the discussion above and is omitted. □

The combined effect of these three effects can be complicated. Note, however, that the three effects each depend on δ: the costs of delaying the return of surplus another period directly relate to δ; the level of I_1 depends on δ as the two relevant first order conditions are $\widetilde{R}_1' = 2/\delta^2$ and $\widehat{R}_1' = 2/\delta$; and the two first order conditions for the choice of I_2 are $\widetilde{R}_2' = 1/\delta$ and $\widehat{R}_2' = 2/\delta$. However, if $\delta = 1$ two of these effects disappear. The only remaining effect is that sequential investment allows the seller to avoid being held-up, increasing her incentive to invest. Thus, if $\delta = 1$, $S_2 < S_4$. As R is a continuous function it follows that there is a neighbourhood for δ close to 1 where the surplus from sequential investment exceeds the surplus generated with simultaneous investments. This is summarised in the following remark.

Remark 5.3 *There is a small enough ε such that for any $\delta \in (1-\varepsilon, 1]$ $S_2 < S_4$; that* *is, the surplus from sequential investments exceeds that produced with simultaneous investments.*

Example 5.1 *Consider the case when $R(I_1, I_2) = \alpha ln I_1 + \beta ln I_2$. Figure 5.6 shows the four different utilities for both simultaneous and sequential investments when contracts are both complete and incomplete.*[†] *First note that U_1, the utility when investment is contractible and simultaneous, and U_3, the total utility when both investments are contractible but made sequentially, are equal when $\delta = 1$ as there are no costs of delay. Second, consider the surplus generated when contracts are incomplete. U_2 represents the total surplus with simultaneous investment, while U_4 represents the total surplus with the sequential regime. With low values of δ U_2 exceeds U_4. However, for values of δ greater than about* 0.9 $U_4 > U_2$; *that is, the total surplus from sequential investments exceeds the total surplus with the simultaneous regime.*

It is not possible, however, to establish that the relative difference between the surplus from sequential and simultaneous investments is monotonically increasing. This is because when δ changes, it is impossible to ascertain with general functions how that will translate into a change in I_1 an I_2 and, subsequently, how R will be affected.

Remark 5.4 *No monotonic relationship between the surplus from the simultaneous and sequential systems as δ changes.*

[†] *With simultaneous investment and complete contracts the first-order conditions are $\frac{I_1}{\alpha} = \frac{I_2}{\beta} = 1/\delta$. When contracts are incomplete and investments are simultaneous the first order conditions are $\frac{I_1}{\alpha} = \frac{I_2}{\beta} = 2/\delta$. When investments are sequential and contracts complete: $\frac{I_1}{\alpha} = 1/\delta^2$ and $\frac{I_2}{\beta} = 1/\delta$. Finally, when investments are sequential and contracts incomplete the first order conditions are: $\frac{I_1}{\alpha} = 2/\delta^2$ and $\frac{I_2}{\beta} = 1/\delta$. The specific functions used assume $\alpha = \beta = 5$: that is $U_1(\delta) = 10\delta(\ln 5\delta - 1)$, $U_2(\delta) = 10\delta(\ln 5\delta - 0.5 - \ln 2)$, $U_3(\delta) = 5\delta^2(\ln 5\delta^2 - 1) + 5\delta^2(\ln 5\delta - 1)$ and $U_4(\delta) = 5\delta^2(\ln 5\delta^2 - 0.5 - \ln 2) + 5\delta^2(\ln 5\delta - 1)$.*

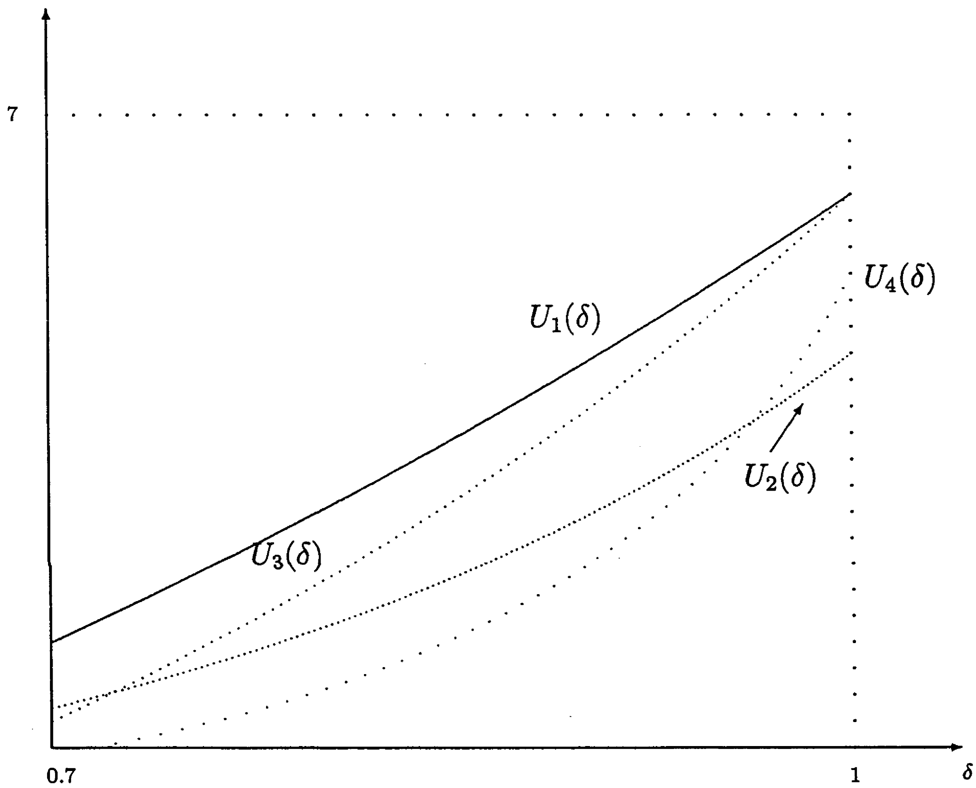

Figure 5.6: Illustration to example 5.1

Example 5.2 *As an example consider the following explicit function where:*

$$f_1 = aI_1^e \tag{5.36}$$

and

$$f_2 = bI_2^c. \tag{5.37}$$

Here, consider the case when $a = 11$, $b = 10$, $c = 0.3$ *and* $e = 0.7$. *Using the explicit solutions to each party's first-order condition, the total utility generated with simultaneous investment can be written as a function of* δ*:*

$$S_2(\delta) = a\delta \left(\frac{ea\delta}{2}\right)^{\frac{e}{1-e}} - \left(\frac{ea\delta}{2}\right)^{\frac{1}{1-e}} + b\delta \left(\frac{cb\delta}{2}\right)^{\frac{c}{1-c}} - \left(\frac{cb\delta}{2}\right)^{\frac{1}{1-c}}. \tag{5.38}$$

Similarly, the total surplus with sequential investment is:

$$S_4(\delta) = a\delta^2 \left(\frac{ea\delta^2}{2}\right)^{\frac{e}{1-e}} - \left(\frac{ea\delta^2}{2}\right)^{\frac{1}{1-e}} + b\delta^2(cb\delta)^{\frac{c}{1-c}} - \delta(cb\delta)^{\frac{1}{1-c}}. \tag{5.39}$$

Figure 5.7 compares these two surpluses. First, there is clearly a non-monotonic relationship between δ *and the difference between* $S_2(\delta)$ *and* $S_4(\delta)$. *Second, the two functions cross twice, once when* δ *is close to* 0 *and another time when* δ *is close to 1.*

5.4.3 Hold-up and the choice of investment regime

Thus far in this section we have considered the relative merits of the various timing arrangements in terms of total welfare. The focus shifts here to explore the incentive for the seller to choose the timing of investments that does not maximise total surplus - in other words to engage in follow-up. Implicit in this discussion is the assumption that the buyer must invest at the beginning of the project. As a result, only the seller has the opportunity to delay her investment and follow-up the buyer.

There is a trade-off for the seller when she chooses between the two regimes. As

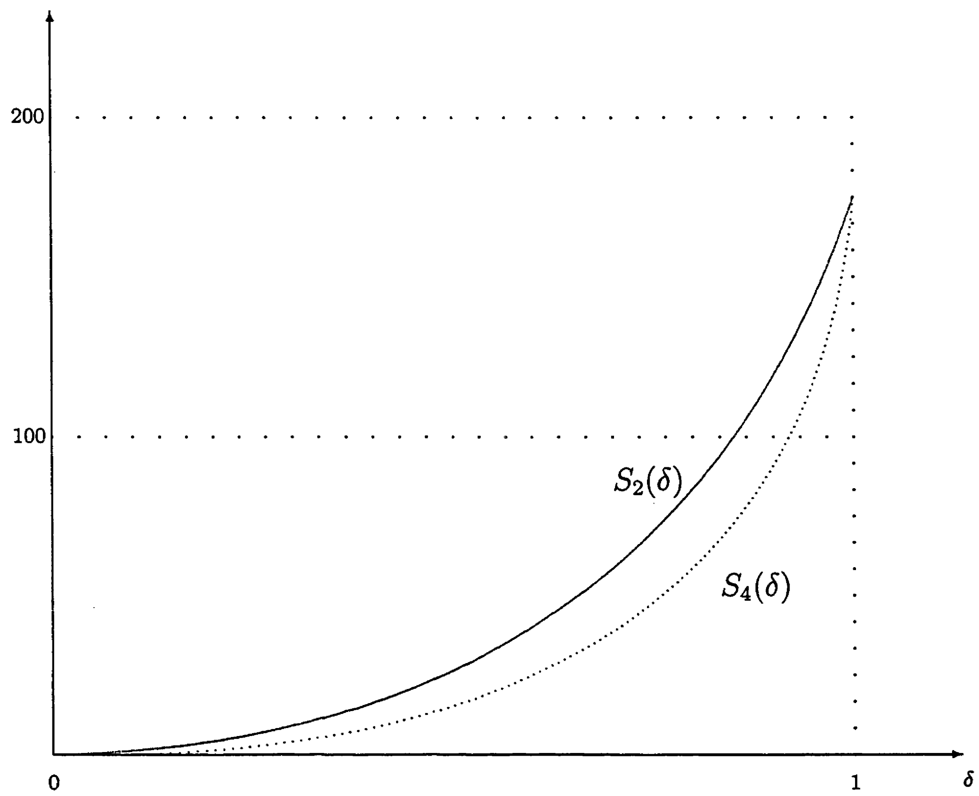

Figure 5.7: Illustration to example 5.2

simultaneous system encourages the buyer to invest, this may allow the seller to capture more surplus during renegotiation. However, sequential investments allow the seller herself to invest without the fear of hold-up. The seller will choose the regime that maximises her welfare. Where her interests differ sufficiently from the first-best incentives the seller will adopt the 'wrong' system, reducing total welfare.

The seller may find it in her interests to adopt the sequential system when simultaneous investments maximise welfare. She will not, however, adopt a simultaneous system when the sequential regime maximises welfare. With inefficient simultaneous investment the seller will lose out on two fronts: first, she will incur hold-up with simultaneous investments; and second, she will be sharing a lower total surplus. Consequently, she will never have any incentive to opt for the simultaneous regime inefficiently.

To further investigate the incentives of the seller assume that $R_{12} = 0$ and that the buyer's level investment is invariant to the seller's choice of regime.† Consequently, I_1 can be suppressed, allowing all attention to revolve around the choice about the timing of I_2. The seller will then choose the system (and the level of investment) that maximises her surplus, regardless of the effect on total welfare.

With simultaneous investments total welfare can be written as

$$\delta\widehat{R} - \widehat{I}_2 \tag{5.40}$$

suppressing I_1, and for the seller's choice of investment $I_2 = \widehat{I}_2$. The seller will set I_2 to maximise

$$\frac{\delta}{2}\widehat{R} - \widehat{I}_2. \tag{5.41}$$

Denote the seller's objective function under the simultaneous regime as v_1; that is, $v_1 = \frac{\delta}{2}\widehat{R} - \widehat{I}_2$. This allows the total welfare generated with simultaneous investments to be written as $2v_1 + \widehat{I}_2$.

With sequential investments total welfare is

$$\delta^2\widetilde{R} - \delta\widetilde{I}_2 \tag{5.42}$$

while the seller's objective function is

$$\frac{\delta^2}{2}\widetilde{R} - \frac{\delta}{2}\widetilde{I}_2. \tag{5.43}$$

Denote the seller's objective functions under sequential investment v_2: that is, $v_2 = \frac{\delta^2}{2}\widetilde{R} - \frac{\delta}{2}\widetilde{I}_2$. This means that total surplus generated with sequential investments

†The buyer's investment may be invariant because it is a discrete choice as in section 5.3. Alternatively, the buyer may have extreme beliefs about the seller's investment strategy: the buyer could be either naive or pessimistic as to whether the seller will opt for the simultaneous or sequential regime.

is $2v_2$.

Now assume that these potential payoffs for the seller are also equal: $v_1 = v_2$. Given that $\widehat{I}_2 > 0$, simultaneous surplus will be greater than the surplus from sequential investments. It is possible, however, to perturb v_2 such that $v_2 > v_1$ while it remains true that simultaneous surplus exceeds the surplus with sequential investments, as $2v_1 + I_2 > 2v_2$. In this case the seller will opt for the sequential regime even though total surplus is maximised with the simultaneous regime. The above discussion is summarised in the result below.

Result 5.5 *There exists a range of parameters for which the seller chooses sequential investments when the simultaneous regime maximises total surplus.*

Example 5.3 *Consider the case when $R = 10lnI_1 + 8lnI_2$. Figure 5.8 plots the surplus of the seller with different investment regimes (on the Y-axis) against δ (on the X-axis). U_{22} shows two times the seller's surplus when investments are made simultaneously. U_4 shows two times the surplus of the seller - this equals the total surplus - when investments are made sequentially. U_2 shows the total surplus of both parties with simultaneous investments. It can be seen that for $\delta > 0.8$ (approximately) the seller will opt for the sequential system over the simultaneous option. However, from U_2 and U_4 it is only when $\delta > 0.95$ (approximately) that the sequential system produces more surplus than simultaneous regime. Thus, for $\delta \in (0.8, 0.95)$ the seller opts for the regime that reduces total welfare. Also note, in this example the buyer's investment is assumed fixed at $\widehat{I}_1$ for all of the functions. The specific functions used are $U_2(\delta) = \delta(10\ln 5\delta + 8\ln 4\delta) - 4\delta$, $U_{22}(\delta) = \delta(10\ln 5\delta + 8\ln 4\delta) - 8\delta$ and $U_4(\delta) = \delta^2(10\ln 5\delta + 8\ln 8\delta) - 8\delta$.*

Now briefly consider the potential effect of non-zero outside options for the parties. As noted in section 5.3 the inability to commit to a particular investment regime can hurt the seller as well as the buyer. Consider the case when the buyer has an outside option b_1 that exceeds his anticipated payoff with sequential investments but is not binding when investment is simultaneous. If the seller prefers the

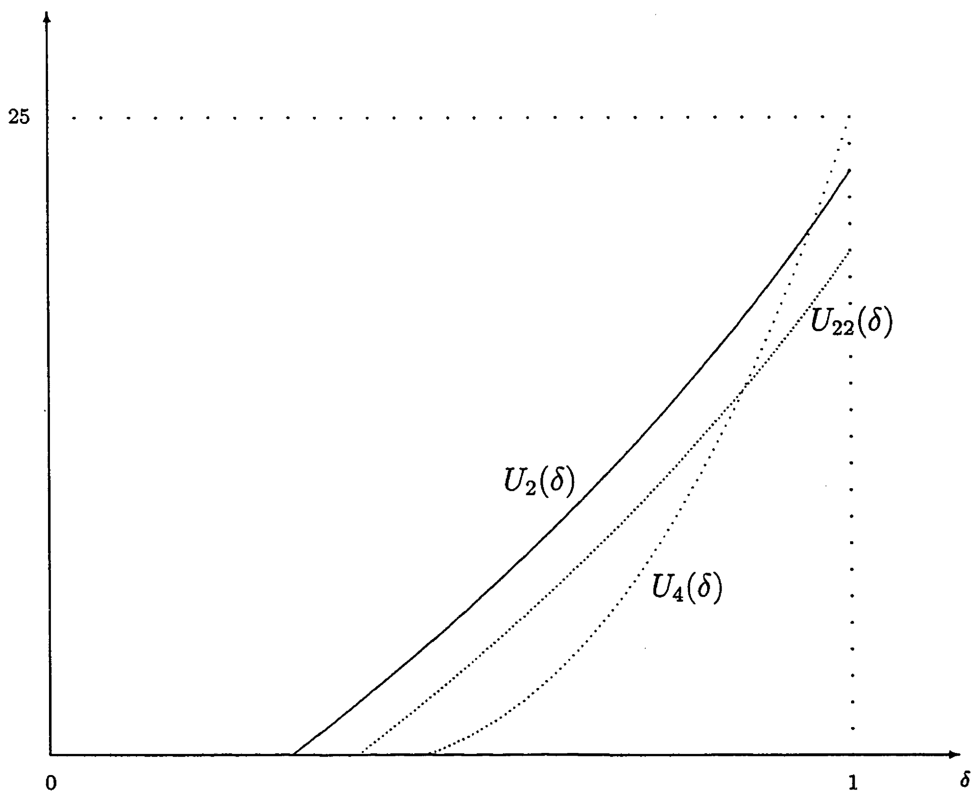

Figure 5.8: Illustration to example 5.3

sequential regime (even if simultaneous investment maximises welfare) the buyer will anticipate that follow-up will occur and decline to take part in the project.[†]

This section derives several results analogous to those discussed in section 5.3. First, the sequential investment regime may produce higher surplus than the simultaneous investment regime. Second, a player can opportunistically opt for an inefficient sequencing regime, reducing the other player's surplus as well as total

[†]If the parties can contract on the buyer not taking up his outside option the seller could share in lower total surplus via her compensation payment to the buyer required to entice him to forfeit his outside option.

welfare. Third, a player may be made worse off by having the option to invest sequentially. In this case the seller would prefer to have her hands tied, to be able to commit to a particular system or not have the option at all. This shows that the possibility for sequential investments is not necessarily a way of overcoming the hold-up problem.

5.5 Extensions

This section makes several extensions to the model presented above. First, we explore the relationship between the two systems when I_1 and I_2 are complement or substitute investments. This allows the relative efficiency of each system to be examined when one player's investment decision is highly sensitive with respect to which regime is adopted. Second, the section explores the relative efficiency of each regime when one investment is very important in terms of its contribution to overall surplus. Third, we examine the situation when one party's investment is restricted due to wealth constraints. To conclude the section, we investigate the implications for total welfare when there is a lack of commitment so that either party can trigger renegotiation at any point in time.

5.5.1 Substitute and complementary investments

When investments are complements or substitutes, $R_{12} \neq 0$. As this can significantly complicate matters, assume that $\delta = 1$, as summarised in Assumption 5.11.

Assumption 5.11 $\delta = 1$

When Assumption 5.11 holds the total surplus is

$$S = R(I_1, I_2) - I_1 - I_2 \tag{5.44}$$

with both regimes. For the two regimes each player will choose their level of investment given their respective first order conditions, shown in the Appendix A. Unlike previously, as $R_{12} \neq 0$ an adjustment in one investment will alter the marginal productivity of the other player's investment: this will affect the player's incentive to invest.

If the cross derivative of the investments is positive ($R_{12} > 0$) the investments are complements as an increase in I_1 enhances the marginal productivity of I_2, as summarised in Definition 5.3.

Definition 5.3 *If $R_{12} > 0$, I_1 and I_2 are complements.*

Complementary investments between trading parties occur in many situations. For example, investment in a convenient location can help enhance the value of the other party's investment. Any effort in learning about the specific requirements of the trading partner enhances the productivity of the other player's investment. Similarly, investing in machinery or retooling in such a way to fit the requirements of the trading partner can help increase the marginal product of the other investment.

First, consider the case when investments are simultaneous. As one of the parties shades their investment, this encourages the other party to also shade their investment. The overall effect is that both parties reduce their investments further below their first-best levels. This is the familiar underinvestment of the hold-up literature when there are externalities.† As a consequence, when investments are simultaneous and the investments are complementary there is underinvestment in both I_1 and I_2. This is summarised in Result 5.6.

Result 5.6 *When the investments are complements and made simultaneously, there is underinvestment in both I_1 and I_2.*

Now consider when $R_{12} < 0$.

Definition 5.4 *If $R_{12} < 0$, I_1 and I_2 are substitutes.*

An example of substitute investments is when the two parties both require the use of a third asset the supply of which is fixed or severely limited, such as a

†See De Fraja (1999).

particular location or venue.† In this case, the buyer using the asset reduces the seller's return on any investment because their use of the asset is subsequently limited.

It is shown in the Appendix A that the overall impact on I_1 and I_2 is ambiguous when investments are made simultaneously. For example, if the seller shades her investment level the buyer has an incentive to increase I_1. Provided that the substitutability of the investments, as measured by the absolute size of R''_{12}, exceeds the effect of diminishing returns to investment, as measured by the absolute value of R''_{22}, the buyer will have an incentive to increase his investment above the first-best level. Similarly, there can be over-investment in I_2 provided that the substitutability of the investments outweighs the negative effect of the diminishing returns of investment ($| R''_{12} | > | R''_{11} |$). In addition, it follows from the assumption of concavity that there will be underinvestment in at least one of the investments, even if there is over-investment in one of the investments.† The above discussion is summarised in the following result.

Result 5.7 *When the investments are substitutes and made simultaneously there can be under or over-investment in I_1 and I_2, however, there will be underinvestment in at least one of the investments.*

Now consider when investments are made sequentially. The buyer will under-invest regardless as to whether the investments are complements or substitutes, as was the case when $R_{12} = 0$. In regards to I_2, when the investments are complements the seller also underinvests. (Note that when $R_{12} = 0$ the sequential regime encouraged the seller to set I_2 at the first-best level.) This is because, unlike when $R_{12} = 0$, the underinvestment in I_1 reduces the incentive for the seller to invest in I_2.

†Another example could be a negative externality between the parties. See, for example, Pitchford and Snyder (1999). Alternatively, if the two parties both produce a byproduct or pollutant, the output of which is limited by government regulation, an increase in output by one party limits the permissible output by the other.

†For details see Appendix A.

In contrast, when the investments are substitutes the underinvestment in I_1 by the buyer provides an incentive to the seller to overinvest in I_2 . The following result summarises the above discussion.

Result 5.8 *When investment is sequential, there is underinvestment in I_1. When investments are complements there is also underinvestment I_2 while if investments are substitutes there is overinvestment in I_2.*

This subsection has explored the situation when investment by one party affects the marginal productivity of the other's investment, either in a negative or positive manner. It was shown previously that when $R_{12} = 0$ the relative welfare of the two systems depended on the interaction of three effects. When the investments are either complements or substitutes these three effects are complicated somewhat by the impact each investment can have on each other. The next subsection extends this analysis further, notably by relaxing the assumption that $\delta = 1$.

5.5.2 Substitutes and complements with hyper-incentives

To further explore this issue consider the following specific functional form:

$$R = f_1(I_1) + f_2(I_2) + \varepsilon I_1 I_2 \tag{5.45}$$

such that total surplus with simultaneous investment is

$$\delta R - I_2 - I_1 \tag{5.46}$$

and total surplus with sequential investment is

$$\delta^2 R - I_1 - \delta I_2. \tag{5.47}$$

With this function, when $\varepsilon < 0$ the investments are substitutes and when $\varepsilon > 0$ they are complements.

With the simultaneous regime, the first order conditions for each party are:

$$\widehat{f_1'} = \frac{2}{\delta} - \varepsilon \widehat{I}_2; \tag{5.48}$$

and

$$\widehat{f_2'} = \frac{2}{\delta} - \varepsilon \widehat{I}_1. \tag{5.49}$$

When investment is sequential the relevant first order conditions are:

$$\widetilde{f_1'} = \frac{2}{\delta^2} - \varepsilon \widetilde{I}_2; \tag{5.50}$$

and

$$\widetilde{f_2'} = \frac{1}{\delta} - \varepsilon \widetilde{I}_1. \tag{5.51}$$

If $|\varepsilon|$ is small the complementarity or substitutability between I_1 and I_2 will be outweighed by effects 5.1, 5.2 and 5.3, outlined when the investments are independent ($\varepsilon = 0$). As the impact of ε is relatively small it remains the case that $\widehat{I}_1 > \widetilde{I}_1$ and $\widehat{I}_2 < \widetilde{I}_2$, in a similar manner as to when $R_{12} = 0$. Further, there are the same welfare trade-offs between the regimes, namely that simultaneous investment increases the contribution to total welfare from I_1 while the surplus generated by I_2 is enhanced with sequential investment. This is summarised in the following remark.

Remark 5.5 *When $R = f_1(I_1) + f_2(I_2) + \varepsilon I_1 I_2$, provided the investments are not strong complements or substitutes the same three effects outlined in section 5.4 determine the relative welfare of the simultaneous and sequential regimes. Note, the directions of these three effects remain unchanged, although the values may be different.*

Proof. See Appendix A. □

When $|\varepsilon|$ is large the effects arising from the interaction between investments can lead to other possibilities. For example, if $\varepsilon > 0$ it is possible for any one of the relevant first-order conditions to be less than zero. This provides that party with the incentive to invest ∞; given the complementarity between investments, the other party will also invest ∞, and the first-best will be achieved (ignoring the costs of delay). Another interpretation is that the first party will invest as much as they can, given their budget constraint. Again, this will encourage the other party to increase their investment. When a party's derivative is negative, this produces a 'hyper-incentive' for that party to invest. This term is defined below.

Definition 5.5 *A hyper-incentive is created when the first-order condition for a party is negative.*

Interestingly, one regime may produce a negative first-order condition while the other may not. For example, the simultaneous regime may produce a negative first-order condition for the buyer while the sequential system remains positive. In this case, the simultaneous regime produces a hyper-incentive for the buyer to invest - this means that this regime is favoured over the alternative. On the other hand, the sequential regime may produce a hyper-incentive for the seller, while her first-order condition with the simultaneous may still be positive. It is not the case that the sequential regime is always preferred, however, as the sequential regime involves additional costs of delay. For sequential investment to be favoured these costs of delay must be outweighed by the extra surplus generated from the hyper-incentive. The above discussion is summarised in the following result.

Result 5.9 *When the simultaneous regime creates a hyper-incentive for the buyer it is favoured over the sequential regime. When sequential investments generates a hyper-incentive for the seller it is favoured over the simultaneous investment regime, provided the players are sufficiently patient.*

Of course, when both systems generate hyper-incentives for a particular party simultaneous investment is preferred as it avoids some costs of delay.

The discussion above of hyper-incentives has an analogue in the property rights literature. For example, Hart (1995) suggested that property rights be allocated to the party whose investment decision is responsive to asset ownership. Similarly, here the favoured timing of investment is the regime that favours the party with the hyper-incentives.

In this subsection we have relaxed the assumption that $\delta = 1$ when the investments are either complements or substitutes. When the complementarity or substitutability between I_1 and I_2 is sufficiently small the same welfare trade-offs apply as when $R_{12} = 0$: the simultaneous regime encourages investment in I_1 and lowers costs of delay while the sequential regime encourages investment in I_2. With significant interaction between the investments the matter is further complicated so that other outcomes are possible.

5.5.3 Important investments and timing

From effects 5.2 and 5.3 above, sequential investments favour I_2 while simultaneous investments favour I_1. As a consequence, when I_1 is very important relative to I_2 the simultaneous investment system is preferred over sequential investments. Using similar reasoning, when I_2 is very important relative to the unimportant I_1 the sequential system is favoured over the simultaneous investment system.

To see this, we adopt a variant of Hart's (1995) definition of an unimportant investment.[†] For simplicity we assume $f_1(0) = f_2(0) = 0$.

Definition 5.6 *I_1 is unimportant if: $R(\widetilde{I}_1, I_2) = \delta^2 f_1(\widetilde{I}_1) + \delta^2 f_2(I_2) - \widetilde{I}_1 - \delta I_2$ is close to $R(0, I_2) = \delta^2 f_2(I_2) - \delta I_2$; and $R(\widehat{I}_1, I_2) = \delta f_1(\widehat{I}_1) + \delta f_2(I_2) - \widehat{I}_1 - I_2$ is close to $R(0, I_2) = \delta f_2(I_2) - I_2$. Similarly, I_2 is unimportant if: $R(I_1, \widetilde{I}_2) = \delta^2 f_1(I_1) + \delta^2 f_2(\widetilde{I}_2) - I_1 - \delta \widetilde{I}_2$ is close to $R(I_1, 0) = \delta^2 f_1(I_1) - I_1$; and $R(I_1, \widehat{I}_2) = \delta f_1(I_1) + \delta f_2(\widehat{I}_2) - I_1 - \widehat{I}_2$ is close to $R(I_1, 0) = \delta f_1(I_1) - I_1$.*

The key element here is that when a particular investment is unimportant it contributes relatively little to total surplus, although the marginal incentive to invest for the relevant player is unchanged.[†] The term 'close to' in Definition 5.6 can be considered as equivalent to the statement that A is close to B iff $A \gg A - B$.

[†]See Hart (1995), p. 44.

[†]The first order conditions for both players are unchanged from the initial problem. With simultaneous investments $f_i'(I_i) = \frac{2}{\delta}$ for $i = 1, 2$. With sequential investments the first order condition for the buyer is $f_1'(I_1) = \frac{2}{\delta^2}$ and the seller's first order condition is $f_2'(I_2) = \frac{1}{\delta}$.

First consider when I_2 is unimportant. Using the definition above, if I_2 is unimportant total surplus with simultaneous investment, $\delta f_1(I_1) + \delta f_2(I_2) - I_1 - I_2$, can be replaced by

$$\delta f_1(I_1) - I_1. \tag{5.52}$$

As a result all that matters to overall welfare is I_1. Surplus is then maximised by the system that promotes the highest level of I_1. As noted above, the level of I_1 with simultaneous investments, $\widehat{I}_1$, is closer to the first best level than $\widetilde{I}_1$. Following from Definition 5.6:

$$R(\widehat{I}_1, \widehat{I}_2) \cong \delta f(\widehat{I}_1) - \widehat{I}_1 > R(\widetilde{I}_1, \widetilde{I}_2) \cong \delta^2 f(\widetilde{I}_1) - \widetilde{I}_1. \tag{5.53}$$

A similar argument can be made when I_1 is unimportant. In this case the sequential regime provides the seller with greater incentive to invest efficiently. There is, however, additional costs of delay with the sequential regime as compared with the simultaneous regime. The sequential regime will only be preferred if the benefits from the seller's additional investment outweigh these delay costs. From Definition 5.6 the total surplus with simultaneous investments is $\delta f(\widehat{I}_2) - \widehat{I}_2$, whereas the total surplus with sequential investments is given by $\delta^2 f(\widetilde{I}_2) - \delta \widetilde{I}_2$. The following result summarises this discussion.

Result 5.10 *When I_2 is unimportant the simultaneous investment system maximises total welfare. When I_1 is unimportant either regime may maximise total welfare.*

This result parallels Proposition 2(B) in Hart (1995). Hart argued that when one investment was unproductive asset ownership would be organised as to give the other party as much incentive to invest as possible. The model presented here suggests that when one investment is relatively unimportant the timing of investment should provide as much incentive as possible to the other party (ignoring the costs of delay). As in Hart (1995) there is no need to worry about the loss of surplus from reducing the other player's investment because it contributes relatively little to investment.

5.5.4 Wealth constraints

As alluded to in section 5.5.2, parties may be wealth constrained limiting their ability to invest. In the extreme, the wealth constraint will be binding with both systems. Consequently, the investment by that party will be the same with either regime. This inelasticity can be utilised by concentrating on maximising the incentive for the other party to invest.

If the buyer is wealth constrained so that they will always invest $\overline{I}_1$, the sequential regime enhances the seller's incentive to invest, however, there is an additional cost of delay. In terms of maximising welfare, these two factors work against each other. As a result, either regime could maximise welfare when the buyer's wealth constraint is always binding. Alternatively, when the seller is wealth constrained, say to $\overline{I}_2$, the simultaneous regime both encourages greater investment by the buyer and reduces the cost of delay. In this case the simultaneous regime is unambiguously superior. This discussion is summarised in the following result.

Result 5.11 *When the buyer is wealth constrained and this constraint is binding under both regimes, there is an ambiguous relationship between regime type and total welfare. If the seller is wealth constrained, and this constraint is binding under both regimes, simultaneous investments is unambiguously superior in terms of total surplus.*

Proof. The proof follows from the discussion above and is omitted. □

This result is similar to Proposition 2(A) in Hart (1995, p. 45). There, if one party's incentive to invest is invariant to asset ownership the other party should own the assets in order to encourage more efficient investment. Similarly here, when one party's incentive to invest is inelastic to the regime adopted because of a binding wealth constraint, the regime chosen should maximise the incentive for the other party to invest. The only complication here is that the cost of delay also need to be taken into account. For example, if the generation of additional surplus from more efficient investment by the seller with the sequential regime does not outweigh the costs of delay, the simultaneous system should still be adopted.

5.5.5 Renegotiation

Grout (1984) noted that industrial relations contracts are often not binding. Similarly, in an 'at-will' contracting environment either party can unilaterally trigger renegotiation or terminate the contract if they wish.† In this section we assume that either party can trigger renegotiation at any point in time.

When this is the case, only the final renegotiation affects the distribution of surplus (and hence the incentive to invest). The last opportunity to renegotiate occurs after the last investment has been made, that is, once I_2 has been completed. Renegotiation will always occur at this stage because the buyer is better off with a new distribution of surplus after I_2 is sunk.

First consider when investment is simultaneous. As before, renegotiation will occur after both investments have been made. Consequently, the first order conditions for both players are the same as described above. With sequential investment renegotiation will always occur after the seller has invested. As both investments are sunk the parties will split the surplus 50-50. The buyer will set his investment to maximise:

$$\frac{\delta^2}{2}[R(I_1, I_2)] - I_1. \tag{5.54}$$

His first order condition under these circumstances will be

$$R_1' = \frac{2}{\delta^2} \tag{5.55}$$

which is unchanged from when there is no subsequent renegotiation. Label the level of the buyer's investment when commitment is not possible with sequential

†See the discussion of 'at-will' contracts in Malcomson (1997). The contracts in this subsection are slightly different from a typical 'at-will' contract environment. Usually in an 'at-will' environment there is an asymmetry in the bargaining power between the buyer and the seller. For example, if the buyer (firm) starts negotiations and proposes a new lower price, the seller (worker) is taken to have accepted this new proposed contract if she continues to supply her services (labour). On the other hand, if the seller attempts to raise price the default price takes precedence, unless the buyer explicitly accepts the new contract.

investment as $\tilde{\tilde{I}}_1$. From this it can be seen that

$$\tilde{\tilde{I}}_1 = \tilde{I}_1 < \widehat{I}_1. \tag{5.56}$$

On the other hand, the seller will maximise:

$$\frac{\delta^2}{2}[R(I_1, I_2)] - \delta I_2 \tag{5.57}$$

which yields the first order condition

$$R_2' = \frac{2}{\delta}. \tag{5.58}$$

Label the seller's choice of her investment when commitment is not possible at any stage and investment is sequential as $\tilde{\tilde{I}}_2$. Comparing the first order condition for the seller when there is simultaneous investment ($R_2' = \frac{2}{\delta}$) and when investment is sequential but there is no after-investment renegotiation ($R_2' = \frac{1}{\delta}$) it can be seen that

$$\tilde{\tilde{I}}_2 = \widehat{I}_2 < \tilde{I}_2. \tag{5.59}$$

If there is ex post renegotiation it does not matter that the investments were initially made sequentially as both parties suffer from hold-up. As the buyer is always held-up, assuming $R_{12}'' = 0$, his incentive to invest is unchanged from the usual sequential regime discussed above. Now, however, any potential advantage of the sequential regime is eliminated: the seller also suffers from hold-up with the sequential regime reducing her incentive to invest. As the sequential system involves more costs of delay, the simultaneous system produces higher total surplus than the sequential regime. Consequently, if commitment is not possible, simultaneous investment is strictly preferred to sequential investment. Moreover the ability of either party to trigger renegotiation at any time effectively renders the possibility of sequential investment (or its attractiveness) redundant. This is summarised in the following result.

Result 5.12 *If the parties cannot commit not to renegotiate after both investments have been made, the simultaneous system strictly dominates sequential investment for $\delta < 1$ in terms of total welfare as well as welfare of the seller. Consequently, the possibility of renegotiation of this sort eliminates the feasibility of sequential investment.*

Proof. The proof follows directly from the discussion above. □

This lack of commitment may be advantageous, however, if the seller would like to commit not to adopt the sequential regime (as discussed in section 5.3). The knowledge that the buyer will trigger renegotiation acts as a credible commitment by the seller to invest simultaneously. This may in turn encourage the buyer to invest.

5.6 Conclusion

This paper develops a model in which two parties can invest in a mutually beneficial project together at the same time (simultaneous investment) or they can choose to have the investments made one after the other (sequential investment). It is assumed that contracting on any future investment becomes possible after some investment has been made as it allows the project to become more clearly defined. Consequently, the advantage of the sequencing of investments is it allows the party that has delayed making their investment to avoid being held-up. The disadvantage of staging is that it reduces the incentive to invest of the first-mover. This can also have feed-back effects on the second party's investment depending on the relationship between the two investments. However, sequencing of investment lengthens the time from the start of the project until the returns are realised, reducing the ex ante value of total surplus when parties discount future returns. The relative advantage of the sequential versus the simultaneous investment regime depends on the precise nature of these trade-offs.

Much of the emphasis in the existing literature has focused on how staging investments can improve welfare when there are incomplete contracts or when parties are unable to commit. In the model presented in this paper it is demonstrated that, in some cases, the option of sequencing investments can reduce welfare. It is shown that under certain conditions a party will opportunistically opt for the sequential regime, reducing total surplus. We interpret this possibility as a new form of hold-up and term it 'follow-up'. Moreover, in some cases the mere possibility that investment can be made sequentially may discourage investment by one party, preventing trade from occurring and reducing welfare of both players.

5.7 Appendix A

Lemma 5.1 *$\delta f_1(\widetilde{I}_1) - \widetilde{I}_1 < \delta f_1(\widehat{I}_1) - \widehat{I}_1$, and $\delta f_2(\widetilde{I}_2) - \widetilde{I}_2 > \delta f_2(\widehat{I}_2) - \widehat{I}_2$.*

Proof. The first-best investment level of I_1, derived from $\delta f_1(I_1) - I_1$, occurs when $f_1' = \frac{1}{\delta}$. This level of investment is termed I_1^*. For $I_1 < I_1^*$, $f_1'(I_1) \geq \frac{1}{\delta}$ because $f_1''(I_1) \leq 0$. For $I_1 < I_1^*$, $[\delta f_1(I_1) - I_1]' \geq 0$, hence $\delta f_1(I_1) - I_1$ is a non-decreasing function $\forall\ I_1 \in [0, I_1^*)$, which means $\delta f_1(\widetilde{I}_1) - \widetilde{I}_1 < \delta f_1(\widehat{I}_1) - \widehat{I}_1$. A similar argument applies to I_2. □

Result 5.6 *When the investments are complements and made simultaneously, there is underinvestment in both I_1 and I_2.*

Proof. When Assumption 5.11 holds the total surplus is

$$S = R(I_1, I_2) - I_1 - I_2 \tag{5.60}$$

for the levels of investment chosen in the different systems. The first order conditions are

$$\widehat{R}_1' = 2 \tag{5.61}$$

$$\widehat{R}_2' = 2 \tag{5.62}$$

for the simultaneous investment system, and

$$\widetilde{R}_1' = 2 \tag{5.63}$$

$$\widetilde{R}_1' = 1 \tag{5.64}$$

with sequential investments.

To investigate this further, replace substitute $a \in [1, 2]$ for 2 in each of the equations, so that

$$\widehat{R}_1' = a \tag{5.65}$$

$$\widehat{R}_2' = a \tag{5.66}$$

for the simultaneous investment equations, and

$$\widetilde{R}_1' = a \tag{5.67}$$

$$\widetilde{R}_1' = 1 \tag{5.68}$$

for the sequential system. This allows the buyer and seller's investment levels to be represented as functions of a: from equations 5.65 and 5.66 the relevant investment levels become $\widehat{I}_1(a)$ and $\widehat{I}_2(a)$; and from equations 5.67 and 5.68 $\widetilde{I}_1(a)$ and $\widetilde{I}_2(a)$ are the relevant investment levels. Totally differentiating equations 5.65 and 5.66 with respect to a yields

$$R_{11}''I_1'(a) + R_{12}''I_2'(a) = 1 \tag{5.69}$$

$$R_{21}''I_1'(a) + R_{22}''I_2'(a) = 1. \tag{5.70}$$

Solving this system of equations using Cramer's rule yields solutions

$$\widehat{I}_1'(a) = \frac{R_{22}'' - R_{12}''}{R_{11}''R_{22}'' - (R_{12}'')^2} \tag{5.71}$$

$$\widehat{I}_2'(a) = \frac{R_{11}'' - R_{12}''}{R_{11}''R_{22}'' - (R_{12}'')^2}. \tag{5.72}$$

Note that given the assumption of concavity the denominator is always negative.

When $R_{12} > 0$,

$$\widehat{I}_1'(a) < 0 \tag{5.73}$$

$$\widehat{I}_2'(a) < 0. \tag{5.74}$$

The overall effect of moving from the first-best level of investment (when $R_i' = 1$) to the second best solutions given by equations 5.61 and 5.62, must consider the integral of the marginal changes over the entire range of $a \in [1, 2]$. However, as the marginal change is always of the same sign we can discern that when the investments are complements there is underinvestment of both investments. □

Result 5.7 *When the investments are substitutes and made simultaneously there* *can be under or over-investment in I_1 and I_2, however, there will be underinvestment in at least one of the investments.*

Proof. From equations 5.71 and 5.72, when $R_{12} < 0$,

$$\widehat{I_1}(a) \gtrless 0 \tag{5.75}$$

$$\widehat{I_2}(a) \gtrless 0. \tag{5.76}$$

For I_1, the derivative is positive if $\mid R''_{12} \mid > \mid R''_{22} \mid$. Likewise, the derivative for I_2 is positive if $\mid R''_{12} \mid > \mid R''_{11} \mid$. In addition, it follows from the assumption of concavity that $I'_1(a) + I'_2(a) = \frac{R''_{22}+R''_{11}-2R''_{12}}{R''_{11}R''_{22}-(R''_{12})^2} < 0$. This suggests that there will be underinvestment in at least one of the investments, even if there is over-investment in one of the investments. □

Result 5.8 *When investment is sequential, there is underinvestment in I_1. When investments are complements there is also underinvestment I_2 while if investments are substitutes there is overinvestment in I_2.*

Proof. As above, totally differentiating the equations 5.67 and 5.68 yields

$$R''_{11}I'_1(a) + R''_{12}I'_2(a) = 1 \tag{5.77}$$

$$R''_{21}I'_1(a) + R''_{22}I'_2(a) = 0. \tag{5.78}$$

Solving using Cramer's rule shows that

$$\widetilde{I_1}(a) = \frac{R''_{22}}{R''_{11}R''_{22} - (R''_{12})^2} \tag{5.79}$$

$$\widetilde{I_2}(a) = \frac{-R''_{12}}{R''_{11}R''_{22} - (R''_{12})^2}. \tag{5.80}$$

Regardless of the sign of R_{12},

$$\widetilde{I_1} < 0. \tag{5.81}$$

This indicates that there will be underinvestment in I_1.

For I_2, when the investments are complements - that is when $R''_{12} > 0$ - there is underinvestment in I_2 as

$$\overrightarrow{I_2} < 0. \tag{5.82}$$

When $R''_{12} < 0$,

$$\overrightarrow{I_2} > 0 \tag{5.83}$$

indicating that there will be over-investment in I_2. □

Remark 5.5 *When* $R = f_1(I_1) + f_2(I_2) + \varepsilon I_1 I_2$, provided the investments are not strong complements or substitutes the same three effects outlined in section 5.4 determine the relative welfare of the simultaneous and sequential regimes. Note, the directions of these three effects remain unchanged, although the values may be different.

Proof. Let us consider the following parameterised first-order conditions

$$f_1'(I_1) = a - \varepsilon I_2 \text{ and } f_2'(I_2) = b - \varepsilon I_1. \tag{5.84}$$

The following equation on the optimal level of I_1 can be derived from the above system:

$$f_2'\left(\frac{a - f_1'(I_1)}{\varepsilon}\right) = b - \varepsilon I_1. \tag{5.85}$$

Differentiating this equation with respect to I_1 when $b =$ constant and $a = a(I_1)$ gives

$$f_2''(\cdot)\frac{a' - f_1''(\cdot)}{\varepsilon} = -\varepsilon, \tag{5.86}$$

which means

$$\frac{\partial I_1}{\partial a} = \frac{1}{a'} = \frac{f_2''(\cdot)}{f_2''(\cdot)f_1''(\cdot) - \varepsilon^2} < 0. \tag{5.87}$$

Similarly when $a =$ constant and $b = b(I_1)$ differentiating of equation 5.85 with respect to I_1 gives

$$f_2''(\cdot)\frac{-f_1''(\cdot)}{\varepsilon} = b' - \varepsilon, \tag{5.88}$$

from which it follows

$$\frac{\partial I_1}{\partial b} = \frac{1}{b'} = \frac{\varepsilon}{\varepsilon^2 - f_2''(\cdot)f_1''(\cdot)} > 0. \tag{5.89}$$

When $|\varepsilon|$ is small the effect outlined in equation 5.89 can be ignored. Consequently, equation 5.87 has the dominant effect. From this we know that I_1 is higher with simultaneous investment than with the sequential regime, and that I_1 is greater still with complete contracts (first-best I_1). Further, in a similar manner as outlined in Lemma 5.1, higher levels of I_1 translate to a greater contribution to total surplus. We can rank the regimes in terms of the contribution I_1 makes to welfare: the simultaneous regime dominates the sequential regime.

We now derive the equation on the optimal level of I_2 from the parameterised system

$$f_1'\left(\frac{b - f_2'(I_1)}{\varepsilon}\right) = a - \varepsilon I_2. \tag{5.90}$$

Differentiating this equation with respect to I_1 when: $b =$ constant and $a = a(I_1)$; and when $a =$ constant and $b = b(I_1)$ gives

$$\frac{\partial I_1}{\partial a} = \frac{1}{a'} = \frac{\varepsilon}{\varepsilon^2 - f_2''(\cdot)f_1''(\cdot)} > 0 \tag{5.91}$$

and

$$\frac{\partial I_1}{\partial b} = \frac{1}{b'} = \frac{f_1''(\cdot)}{f_2''(\cdot)f_1''(\cdot) - \varepsilon^2} < 0 \tag{5.92}$$

respectively.

In a similar manner as described with I_1 above, when $|\varepsilon|$ is small the effect outlined in equation 5.92 has the dominant influence on I_2. This suggests I_2 is greater with the sequential regime than with simultaneous investments, although it is still lower than its first-best level. The levels of I_2 also directly translate into its contribution to total welfare: I_2 contributes more to total welfare with sequential investment than with the simultaneous regime. □

Example 5.4 *The following example examines the possibility of chaotic switching* *between prisoners' dilemma and a coordination game when there are many potential investment periods.*

Let $\delta = 0.9$, $f = 10$ and R=100. Figure 5.9 illustrates the normal form game of the investment decision of either party when there are $n = 1, 2 \ldots$ potential investment periods.

		Seller	
		I	II
Buyer	I	A, A	B, C
	II	C, B	D, D

Figure 5.9: Normal form for n period game

From Figures 5.3, 5.4 and 5.5 the payoffs are $A = 35$, $B = 26$, $C = 36$ and $D = \delta^n 35$. For $n = 1$, 2 and 3 we have a prisoners' dilemma. For $n = 4$ we get a coordination game. Let us show that for $n = 5$ we are back to a prisoners' dilemma.

If the buyer chooses the first and the second strategies with probabilities α and $1 - \alpha$ respectively, while the seller does the same thing with probabilities β and

$1 - \beta$, the expected return of the buyer is

$$A\alpha\beta + B\alpha(1-\beta) + C\beta(1-\alpha) + D(1-\alpha)(1-\beta). \tag{5.93}$$

To get a Nash Equilibrium in mixed strategies we find β such that the payoff to the buyer does not depend on α, in other words

$$\beta = \frac{B-D}{B+C-A-D}. \tag{5.94}$$

Similarly, when the payoff to the seller does not depend on β

$$\alpha = \frac{B-D}{B+C-A-D}. \tag{5.95}$$

The payoff to the buyer from playing this mixed strategy is

$$D + (C-D)\frac{B-D}{A+C-A-D} = \frac{BC-AD}{B+C-A-D} = B + \frac{(A-B)(B-D)}{B+C-A-D}. \tag{5.96}$$

Because $C > A > B > D$ this payoff is always greater than B and if the discount factor is sufficiently high - we are back to a prisoners' dilemma in period $n = 5$. In this specific example as $\delta = 0.9$ the relevant payoff for period $n = 5$ is $\frac{BC-AD}{B+C-A-D}\delta$ which is greater than B. On the other hand, if δ were small enough we could end up in the coordination game $\forall\ n \geq 4$. Thus, in general case it is impossible to discern the exact structure of the game when $n \to \infty$. The structure is chaotic.

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