Sequential Bargaining with Public Intervention: The Optimal Subsidy Path

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Abstract

Models of sequential bargaining under asymmetric information often exhibit equilibria which are characterised by the fact that agreement is reached only with a delay and that the final (period) solution is ex ante inefficient. The latter means that agreement is not reached though it is efficient (aggregate pay off exceeds aggregate costs). In this paper we analyse how intervention by a third agent in a sequential bargaining process, modelled as a durable goods monopoly, affects the (high path) equilibrium outcome. The effects of intervention crucially depend on how intervention is formulated. When the intervening agent and the seller decides the price and the subsidy (the intervening agent's contribution) is decided in a Stackelberg game with the intervening agent as the leader the negotiations are always speeded up and equilibrium inefficiency reduced. When the seller acts as a Stackelberg leader the negotiations are only conditionally speeded up and the equilibrium inefficiency only conditionally reduced. For the same values on the reservation prices and discount factor intervention is more likely to take place when the seller acts as a Stackelberg leader. Also, both the seller's price and the subsidy are higher when the seller acts as a Stackelberg leader compared to if the intervening agent acts as a Stackelberg leader.

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1 Introduction

There are several examples of a public body intervening in a bargaining process between (private) agents in order to promote a solution. This is especially the case when the bargaining process tends to be long and delays are costly. In addition, the presence of positive externalities may induce a third party to intervene in order to internalise the externalities. One example of public intervention in a bargaining process is the Government's intervention in the negotiations between central trade unions and employers' organisations about wages and other working conditions. The result of these negotiations has consequences for a large share of the workforce in countries with high rates of membership in trade unions, and thus the result is of macroeconomic importance to a Government. The Government's intervention may be in order to moderate rises in wages and thus in production costs, or, in the case of a conflict, to speed up the process towards a solution. Another example is intervention in negotiations between private traders about implementation of projects, with positive external effects to the society. Typical examples may be implementation of environmental friendly technology and of safety equipment in motor vehicles.

The aim of this paper is to analyse how a public intervention affects the outcome of a sequential bargaining process under asymmetric information.

We apply a durable goods monopoly model and let a public body, henceforth called Government, intervene and offer a subsidy if an agreement is reached. The optimal subsidy-path is decided as a part of the equilibrium. We restrict the analysis to discuss the following two effects of intervention:

1) Does intervention speed up the bargaining process?
2) Does intervention reduce the equilibrium inefficiency (no agreement though this is efficient)?

It can be shown that the answer to these questions crucially depends on the formulation of the intervention, i.e. the procedures for the interaction between the seller and the Government. We consider two alternatives; A: the Government acts as a Stackelberg leader and the seller as a follower when deciding upon subsidy and price respectively, and B: the seller acts as a Stackelberg leader and the Government as a follower.

There is a large literature on durable goods monopoly models, but so far and to our knowledge they are all restricted to encompass two agents (or group of agents). In this paper we show that introducing a third agent in durable goods monopoly negotiations does not affect the presence of an equilibrium outcome of the negotiations. Sobel and Takahashi (1983) show that in the absence of intervention there exists a perfect Bayesian equilibrium that satisfies the Coase dynamics (the price decreases monotonically over time). Extending this model to take into consideration public intervention this conclusion still holds, but the properties of the equilibrium paths now change. Whereas in the original model the solution breaks down with perfectly patient agents, we now get a solution, which follow the Coase dynamics, also when the common discount factor equals one. Conditional on the time costs, reservation values and formulation of the negotiation process an intervention speeds up the negotiation process and increase the equilibrium efficiency. However, the equilibrium is still inefficient, as a solution may not be reached though it would imply an improvement in the Pareto sense.

Models of sequential bargaining under asymmetric information and when there is a probability for no gains from trade (the no-gap situation) exhibit a multitude of equilibria (Fudenberg et al 1985)[i]. One is characterised by the fact that the price will only asymptotically approach the buyer's lowest valuation, and this is ex ante inefficient as there is a probability that trade will not take place within a finite horizon even if there are gains from trade (Sobel and Takahashi 1983). Ausubel and Deneckere (1989, 1993) derive an efficient mechanism for sequential bargaining games with two-sided asymmetric information and offers and where the mentioned equilibrium is a part. However, only with infinite horizon this mechanism provides a generic solution, as the price under certain conditions only asymptotically reaches seller's reservation price.

Introducing a subsidy may change the ex ante information structure of the game in the no-gap case. This will be the case if the value of the subsidy exceeds the seller's reservation price, in which case the intervention implies a transmission to the gap case. A sufficient assumption to avoid this complication of the model and to secure that we are in the no-gap case is that the value of the subsidy is always smaller than the seller's reservation price.

In the models derived in Chambers and Jensen (2002) and Caparros et al (2004) trade takes place within the first two periods even if assuming the gap case. This, however, is due to the fact that the there is one sided asymmetric information and the informed agent only takes one of two types. With a continuum of types their result would not necessarily hold. In the model of Caparros et al (2004) the uninformed agent uses time as a signal to screen the privately informed agent. This is the same as in durable goods monopoly models.

The multitude of equilibria constitutes a problem for models characterised by the no-gap situation. Only under certain conditions it is possible to pin down a single equilibrium in these models. The durable goods monopoly model, which Sobel and Takahashi (1983) were the first to address, has a unique equilibrium characterised by the high price path when the seller is at least as patient as the buyer (Fudenberg and Tirole 1993). This equilibrium is characterised by the Coase dynamics, but the price offered by the seller only asymptotically approaches its reservation price. This equilibrium is also called the high price path.

In a high-price path equilibrium, the seller can make any profit between the monopoly profit and (infinitesimal above) the competitive outcome (op cit). When the number of buyers is limited, or the single buyer's valuation is discrete, Bagnoli et al (1989) show that the "Pacman outcome" is possible, which implies that the seller can perfectly price discriminate and "work her way down the demand curve". Fehr and Kühn (1995) show that a sufficiently high discount factor for the seller (relative to the buyer), and a finite number of buyers secure the Pacman outcome. On the other hand, a sufficient high discount factor for the buyer and a finite number of possible prices to offer secure that in equilibrium the Coase conjecture is followed, in which the buyer extracts the social surplus. The results above are all shown to be valid when there are (only) two players. We show that also in the presence of public intervention in a durable goods monopoly the relative discount factors are of importance for the characteristics of the equilibrium paths.

Myerson and Satterthwaite (1983) show that in a one shot model with asymmetric information the introduction of subsidies increases efficiency. So far, and to our knowledge, there are no corresponding models for sequential bargaining.

Reports from numeric examples and experimental tests of durable goods monopolies and sequential bargaining models show that the ability to commit for the seller provides higher prices along the equilibrium path (Sobel and Takahashi 1983, Reynolds 2000, and Casado-Izaga and Saracho 2002). Güth et al (2002) and Cason and Sharman (2001) show that there is a tendency that the price increases with the length of the bargaining horizon, so that the longer the agents can commit to "participate" in the negotiations the higher will the price path offered by the seller, ceteris paribus. We assume a finite horizon for the game, which may meet the counterargument that the Government may not be able to commit credibly to withdraw after a fixed number of periods. However, a Government in a democratic country will normally not be in power permanently, which is an argument for choosing a definite end to the bargaining situation (though this is not necessarily ex ante commonly known). Though of interest, we do not analyse how the ability to commit to a (long) negotiation-period for all three players affects the equilibrium paths.

The paper is organised as follows: Section Two presents the basic model, derives a high price path equilibrium and analyses the effects of a subsidy on the high price path equilibrium when the subsidy is decided as part of the equilibrium. In Section Three we discuss the equilibrium characteristics, and section Four discusses the analytical results in the light of two relevant empirical cases. Section Five concludes.

2 A durable goods monopoly model with public intervention

2.1 The original model

A monopolist seller of durable goods faces a single, privately informed buyer, whose valuation of the good, *V*, is continuously and uniformly distributed on $\left[\underline{V},\overline{V}\right]$. For simplicity we set $\underline{V}$=0 and $\overline{V}$=1. Seller's costs (reservation price), *C* is common knowledge, and we assume *C>0*. The negotiations have 2 periods. The buyer decides the optimal period to buy, given the dynamic pricing strategy of the seller. If trade takes place when there are *n* periods left the payoff to the seller and the buyer respectively are given by $\delta_S^{\ N-n}(p_n - C)$ and $\delta_B^{\ N-n}(V - p_n)$. δ_S and δ_B are the discount factor of the seller and buyer respectively, p_n is the price offered by the seller when there are *n* periods left, *N = 2* is the number of periods in the negotiations and $n \in [1,2]$. In the case of no trade both agents get a pay-off equal to zero.

Sobel and Takahashi (1983) show that for fixed discount rates, $0 < \delta_B, \delta_S < 1$, there exists a no-commitment equilibrium[ii]. For simplicity and comparability with the model under intervention we present this equilibrium solution assuming a common discount factor, $0 < \delta_B = \delta_S = \delta < 1$.

$$T^*(\delta) = \frac{2-\delta}{4-3\delta} + \frac{2-2\delta}{4-3\delta}C \qquad (1)$$

$$p_2^*(T,\delta) = \frac{(2-\delta)^2}{4-3\delta} + \left(\frac{\delta(4-3\delta)+2(1-\delta)(2-\delta)}{2(4-3\delta)}\right)C \qquad (2)$$

$$p_1^*(T,\delta) = \frac{2-\delta}{2(4-3\delta)} + \frac{6-5\delta}{2(4-3\delta)}C \qquad (3)$$

(1) gives the cut-off value, which is the valuation of the lowest valuation buyer in the first period. (2) and (3) give the price to charge in the first and last period (when there are two and one period left) respectively. This perfect Bayesian equilibrium strategy is stationary, and linear in *T*. It rests on the assumption that buyer's behaviour is characterised by the skimming property (follows the cut-off rule), as defined in Fudenberg and Tirole (1993, p 407). It implies that if a seller with valuation $\hat{v}$ accepts a price p_n when there are n periods left, then all sellers with valuation $v > \hat{v}$ will also accept this price at the same time. It can be shown that $T > p_2 > p_1$ which implies the Coase dynamics.

The intuition behind the seller's strategy is as follows: in the last period a "final" price is fixed, and all buyers with valuation equal to or above this price will accept. In the first period the seller maximises the continuation payoff, which is the aggregate of the payoff in both periods, by deciding the lowest-valuation buyer to sell to in this period, i.e. the cut off value. Based on the cut-off value the seller fixes the optimal price to offer in the first period. The cut-off value, decided in the first period, becomes the exogenously given upper limit for the buyer's valuation in the last period. In a dynamic equilibrium the priors' support is given by *[0, 1]*, whereas the posterior beliefs has a truncated support given by *[0, T*]*, where $T^* < 1$ is the equilibrium cut-off value.

This equilibrium strategy for the seller's price has the following properties: the price is weakly decreasing over time (Coase dynamics), buyer's expectations about future prices are rational, and the seller becomes more pessimistic as to the beliefs about the buyer's valuation when an offer is rejected (Fudenberg and Tirole 1983).

2.2 Introducing subsidies in the durable goods monopoly model

We extend the model presented in Section 2.1 to take into consideration that a third agent, henceforth called Government, intervenes in the bargaining between seller and buyer. Having a positive valuation of an agreement, the Government may offer a subsidy if agreement is reached. We do not take into consideration negative subsidies, i.e. taxation, which means that if the optimal (equilibrium) subsidy is negative in the first period this implies no intervention and we revert to the original, two-agent model presented in the previous section[iii]. The Government's pay off of intervention and if agreement is reached when there are n periods left is given by $\delta^{N-n}\left(W-x_n\right)$, where $W>0$ is the Government's valuation of the agreement, $x_n \geq 0$, is the size of the subsidy offered when there are n periods left of the negotiations, and δ is the Government's discount factor, which is the same, common discount factor as in the original two-agent model. W and δ are exogenously fixed, whereas the subsidy is decided as part of the equilibrium. The subsidy is subtracted from the price offered by the seller, p. Eliminating the possibility for negative prices, the net price (buyer's price), π, in the presence of a subsidy, x, is given by $\pi = \max\{p-x,0\}$. This is valid in each period.

Using the durable good monopoly model the extension of this model to take into account intervention, as described above, can be formulated in two alternative ways[iv]:

A. The seller decides the price as a reaction to the Government's subsidy (Stackelberg game with the Government as the leader and the seller as the follower).

B. The Government decides the subsidy as a reaction to the seller's price (Stackelberg game with the seller as the leader and the Government as the follower).

The crucial difference between alternatives A and B is how the two agents, seller and Government, relate to each other. Remember there is perfect information between these two agents. In formulation A of the model the Government acts as a Stackelberg leader towards the seller when deciding the subsidisation strategy, whereas the seller acts as a Stackelberg follower when deciding it's pricing strategy. In formulation B the opposite is the case, where the seller acts as a Stackelberg leader when deciding the pricing strategy and the Governemnt acts as a follower when deciding it's subsidisation strategy. In both alternatives each period has two stages: first, the seller and the Government offer a price and a subsidy, and the buyer does nothing, second, the buyer either accepts or rejects the joint offer and the seller and the Government does nothing.

In order to remain in the no-gap case we assume that $C - W \geq \underline{V} \equiv 0$. The time between each period may be significant, so that discounting affects the equilibrium strategies. If an offer is accepted when there are *n* periods left of the game, the pay-off to the seller is $\delta^{N-n}(p_n - C)$, and the payoff to the buyer is $\delta^{N-n}(V - p_n + x_n)$, whereas the Government's pay off is given above.

The subsidy may affect the outcome of the original durable goods model in two ways;

i. increase the price offered by the seller

ii. increase the probability of trade

However, there is a trade-off between the two. Both may be achieved, but each of them only at the costs of the other. Thus, the seller and the Government has to choose the optimal (profit-maximising) trade-off between the two effects.

We are looking for equilibrium strategies for the seller and the Government, which in each period and also for the whole game are best replies to each other, and where it is assumed that the buyer's behaviour is characterised by the skimming property. The crucial questions to be analysed are; 1) does intervention speed up the negotiations, and 2) does intervention reduce the equilibrium inefficiency?

Proposition 1

Assume a durable goods monopoly and the existence of a third agent, Government, with a positive valuation of agreement. Let the Government intervene by offering a subsidy, which is deducted from the price the seller offers, if agreement is reached. The buyer pays the net price. In this situation there is a high-price path equilibrium in stationary strategies and where the equilibrium price- and subsidy-paths are functions of the time costs, and linear in the reservation values. The effect of intervention crucially depends on the formulation of the intervention.

A: when the Government acts as a Stackelberg leader in the intervention game the negotiation process is always speeded up and the equilibrium inefficiency always reduced by intervention.

B: when the seller acts as a Stackelberg leader in the intervention game the negotiation process is only conditionally speeded up and the equilibrium inefficiency only conditionally reduced.

Proof

The proof is by backward induction. Assuming a finite horizon the last period can be analysed as a static maximisation problem, where the Stackelberg leader maximises pay off in this period taking into consideration the follower's reaction function. The objective functions are given in the appendix.

When the Government is the Stackelberg leader the last period equilibrium solution is given by

$$x_{1A}* = \frac{C + W - T}{2} \qquad (4A)$$

$$p_{1A}* = \frac{3C + W + T}{4} \qquad (5A)$$

When the seller is the Stackelberg leader the last period equilibrium solution is given by

$$x_{1B}* = \frac{C + 3W - T}{4} \qquad (4B)$$

$$p_{1B}* = \frac{C + W + T}{2} \qquad (5B)$$

Independent of the strategic interaction between seller and Government, the net price in the last period is given by

$$\pi_1* = \frac{C - W + 3T}{4} \qquad (6)$$

T is the cut-off value, which is decided in the first period. In this period the Stackelberg follower decides upon a cut-off value, which is then used to decide the optimal price (subsidy), both as reactions to the strategy of the Stackelberg leader. The Stackelberg leader maximises its continuation pay off taking into consideration the follower's cut-off value, formulated as a reaction to the leaders strategy.

Both seller and Government, independent of the strategic interaction between them, takes into consideration the buyer's decision strategy, which is characterised by the skimming property. Let p_2 and x_2 be the price and the subsidy offered in the first period (in this period there are *2* periods left of the negotiations). The skimming property implies that a buyer with valuation $V = T$ will accept a price $\pi_2 = p_2 - x_2$ in the first period when it expects a price equal to $\pi_1 = p_1(T) - x_1(T)$ in the last period iff

$$T - p_2 + x_2 \geq \delta(T - p_1 + x_1) \tag{7}$$

Substituting p_1 and x_1 in (7) by the equilibrium expressions p_{1i}* and x_{1i}*, i=A,B, and solving for p_2 and x_2 when assuming that (7) is fulfilled with equality we get the following reaction functions for the first period price and subsidy

$$p_{2i} = \left(1 - \frac{\delta}{4}\right)T + \frac{\delta}{4}(C - W) + x_{2i} \qquad i = A, B \tag{8}$$

$$x_{2i} = -\left(1 - \frac{\delta}{4}\right)T - \frac{\delta}{4}(C - W) + p_{2i} \qquad i = A, B \tag{9}$$

In the first period the continuation pay-off to the seller and the Government respectively is given by

$$U_{Si}(W, C, \delta) = \max_{p2i}\left[(p_{2i} - C)(1 - T) + \delta\left((p_{1i} - C)(\frac{T - p_{1i} + x_{1i}}{T}\right)T\right] \qquad i = A, B \; (10)$$

$$U_{Gi}(W, C, \delta) = \max_{x2i}\left[(W - x_{2i})(1 - T) + \delta\left((W - x_{1i})(\frac{T - p_{1i} + x_{1i}}{T}\right)T\right] \qquad i = A, B \; (11$$

When the Government is the Stackelberg leader the seller takes x_{2A} as given, inserts for the last period equilibrium expressions and substitutes p_{2A} by (8). Maximising (10) with respect to T then gives the optimal cut-off value as a reaction to x_{2A} (see appendix). Inserting for the cut-off value in (8) gives the optimal first period price as a reaction to x_{2A}. The Government inserts for the last period equilibrium expressions and for the optimal cut-off value as decided by the seller, and maximises (11) with respect to x_{2A}. Having derived the optimal first period subsidy, this is inserted in the seller's reaction functions (cut-off value and price) to derive the first period equilibrium price and the cut-off value. The first period equilibrium solutions are given by

$$p_{2A}^* = a_{2A} + b_{2A}W + d_{2A}C \qquad (12)$$

$$x_{2A}^* = f_{2A} + g_{2A}W + h_{2A}C \qquad (13)$$

$$\pi_{2A}^* = k_{2A} + m_{2A}W + s_{2A}C \qquad (14)$$

$$T_A^* = t_A + y_A W + d_A C \qquad (15)$$

The parameter expressions are in the appendix.

When the seller is the Stackelberg leader the Government takes p_{2B} as given, inserts for the last period equilibrium expressions in (11) and substitutes x_{2B} by (9). Maximising (11) with respect to T then gives the optimal cut-off value as a reaction to p_{2B} (see appendix). Inserting for the cut-off value in (9) gives the optimal first period subsidy as a reaction to p_{2B}. The seller inserts for the last period equilibrium expressions and for the optimal cut-off value as decided by the Government, and maximises (11) with respect to p_{2B}. Having derived the optimal first period subsidy, this is inserted in the seller's reaction functions (cut-off value and subsidy) to derive the first period equilibrium subsidy and the cut-off value. The first period equilibrium solutions are given by

$$p_{2B}* = a_{2B} + b_{2B}W + d_{2B}C \quad (16)$$

$$x_{2B}* = f_{2B} + g_{2B}W + h_{2B}C \quad (17)$$

$$\pi_{2B}* = k_{2B} + m_{2B}W + s_{2B}C \quad (18)$$

$$T_B* = t_B + y_BW + d_BC \quad (19)$$

The parameters are given in the appendix.

As we have assumed away negative subsidies (taxation), a condition for intervention is $x_{2i}* > 0$, i=A,B. Whether intervention takes place or not depends on the reservation values (C and W), the time costs and the formulation of the intervention game. The formal conditions for intervention in formulation A of the game (Government is the Stackelberg leader) and in formulation B (the seller is the Stackelberg leder) are;

$$x_{2A}*(\delta \to 0) > 0 \qquad C + W > 0 \qquad x_{2A}*(\delta \to 1) > 0 \qquad \frac{93}{67}W + C > 1 \quad (21)$$

$$x_{2B}*(\delta \to 0) > 0 \qquad 3C + W > 0 \qquad x_{2B}*(\delta \to 1) > 0 \qquad \frac{275}{77}W + C > 1 \quad (22)$$

The cut off value, *T*, indicates the buyer with the lowest valuation who possibly will buy in the first period, and the lower the cut off value is the higher is the probability of agreement in the first period. The negotiations are speeded up if $T_i* < T*$., i=A,B, and $T*$ is given in (1). The parameter expressions in the appendix shows that $T_A* = T_B*$ and hence the condition for the negotiations to be speeded up, independent of formulations of the intervention game is

$$\frac{24-\frac{29\delta}{2}+\frac{35\delta^2}{16}+W\left(-8+\frac{15\delta}{2}-\frac{25\delta^2}{16}\right)+C\left(8-\frac{15\delta}{2}+\frac{25\delta^2}{16}\right)}{(2-\frac{5\delta}{8})(16-6\delta)}<\frac{1-\frac{\delta}{2}+C(1-\delta)}{(2-\frac{3\delta}{2})} \quad (23)$$

When $\delta \to 0$, (23) reduces to $W+C>1$, which is coinciding with the condition for intervention when the Government is the Stackelberg leader. This is a stronger condition than the condition for an intervention (positive subsidy) when the seller is the leader, and thus the above condition is binding when the seller is the leader. Hence, when the time costs become very high an intervention with the Government as the Stackelberg leader will always speed up the negotiation process, whereas when the seller is the Stackelberg leader this will only happen conditionally. When $\delta \to 1$, (23) reduces to $C-W<1$, which is a condition for trade being efficient. Hence, if trade is ex ante efficient then intervention will speed up the negotiations and this is the case independent of the formulations of the intervention.

In the last period all buyers with valuation equal to or above the net price will buy. The equilibrium paths do not follow the Coase conjecture as the final price offered to the buyer only asymptotically approaches the seller's costs net of the Government's valuation of trade. As a consequence the equilibrium is ex ante inefficient. However, the lower the final price offered to the buyer is the lower is the efficiency loss. A condition for the intervention to reduce the efficiency loss is thus $\pi_{1i}^* < p_1^*, i = A, B$, where p_1^* is given in (3). From the parameter expressions we can see that the last period net price is the same independent of the formulation of the intervention, and the condition for reduced equilibrium inefficiency, independent of the formulation of the intervention game is fulfilled when

$$\frac{3(24-\frac{29\delta}{2}+\frac{35\delta^2}{16})}{4(16-6\delta)(2-\frac{5\delta}{8})}+W\left(-\frac{1}{4}+\frac{3(8-\frac{15\delta}{2}+\frac{25\delta^2}{16})}{4(16-6\delta)(2-\frac{5\delta}{8})}\right)+C\left(\frac{1}{4}+\frac{3(8-\frac{15\delta}{2}+\frac{25\delta^2}{16})}{4(16-6\delta)(2-\frac{5\delta}{8})}\right)<\frac{1-\frac{\delta}{2}+C(3-\frac{5\delta}{2})}{4-3\delta} \quad (24)$$

When $\delta \to 0$, (24) reduces to $\frac{7}{5}W + C > 1$, and this is automatically fulfilled when there is intervention and the Government is the Stakelberg leader. On the other hand, this is not necessarily fulfilled under intervention when the seller is the leader. Hence, when time costs become very large intervention will always reduce the equilibrium inefficiency when the Government acts as a Stackelberg leader, whereas it will only conditionally reduce the equilibrium inefficiency when the seller acts as the leader.

When δ → 1, (24) reduces to $\frac{319}{121}W + C > 1$. This is automatically fulfilled when the condition for intervention under Government leadership is fulfilled. On the other hand, there are combinations of C and W which allows intervention when the seller is the Stackelberg leader, but which doesn't fulfil the above condition. Hence, an intervention when the time costs approaches zero will always reduce equilibrium inefficiency when the Government is the Stackelberg leader, but will not necessarily do so when the seller is the leader.

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Proposition 2

In a durable goods monopoly with intervention, in the form of a subsidy which is deducted from the seller's price if trade takes place, the formulation of the game between the seller and the Government is of importance for the outcome of the negotiations.

The condition for intervention (positive subsidy) is stronger when the Government acts as a Stackelberg leader. The cut-off value and the last period net price coincides under the two formulations of the game, but due to different conditions for intervention this does not necessarily imply that intervention speeds up the negotiation process and reduces equilibrium inefficiency independent of the formulation of the game (see proposition 1).

When the seller acts as a Stackelberg leader both the price path and the subsidy path is higher compared to when the Government acts as a Stackelberg leader. The first period net price is always higher when the seller acts as a Stackelberg leader.

Proof

Comparing (21) and (22) it is obvious that there are combinations of values for C and W which fulfil the condition for intervention when the seller as a Stackelberg leader (22), but not when the Governments acts as a Stackelberg leader (21). Comparing (A8) and (A16) in the appendix shows that T_A* coincides with T_B*. Similarly, comparing (A7) and (A17) in the appendix shows that π_{1A}* coincides with π_{1B}*.

The condition for $p_{2B}* > p_{2A}*$ is given in the appendix in (A20).

When δ→0, (A20) reduces to $C - W < 1$, which is the condition for trade to be ex ante efficient. When this is not fulfilled negotiations should not end up in agreement because the net costs to society will exceed the valuation of the highest valuation buyer. When δ→ 1, (25) reduces to $\frac{87}{18}W + \frac{5}{3}C > 1$, and it can be shown that this condition is always fulfilled when the conditions for intervention in both the formulations of the game is fulfilled.

Similarly, comparing the equilibrium subsidy in period 1, shows that both when δ→0 and δ→ 1 the condition for $x_{2B}* > x_{2A}*$ is $C - W < 1$, which is the same as above. Hence, given that trade is ex ante efficient the above inequality is always fulfilled.

Correspondingly, it can be shown that the condition both for $x_{1B}* > x_{1A}*$ and $p_{1B}* > p_{1A}*$ is $C - W < 1$, and this is independent of the time costs.

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3 Characterisation of the high-price path equilibrium under intervention

3.1 The general dynamics of the equilibrium solution

Independent of the formulation of the game, the characteristics of the equilibrium solution in most aspects resembles those of the original model without intervention. This implies that the net price (the price offered to the buyer) decreases over time, and as a consequence there is a probability for agreement in each period. This property is independent of the time costs, the reservation values and the formulation of the game. The higher the (common) time costs are, the higher the net price starts out and the quicker it drops.

The seller's price path when the seller is the Stackelberg leader and the subsidy path when the Government is the leader are both time-cost dependent. With high time costs the price decreases over time and the subsidy increases over time, but when the time costs becomes very low these characteristics reverse. We will come back to the dynamics behind these somewhat counterintuitive results.

The cut-off value decreases as the time costs increases. This is the case independent of the formulation of the game between the seller and the Government. With high time costs it is important to get a sale in the first period and the probability for agreement in period one is higher the lower the cut-off value is. The cut-off value decreases in the Government's reservation value (W), and increases in the seller's reservation value (C). It is higher the higher the seller's reservation price is relative to the Government's reservation value. This is intuitive as both a high seller's reservation price and low Government's reservation value contributes to increase the net price.

The seller's pricing strategy when it acts as a Stackelberg leader and the Government's strategy for the subsidy when it acts as a leader need some explanation. In the original game the seller faces a trade off between a high price in the first period and in the second period, and the optimal trade-off depends on the time costs. When time costs are high the value of the first period pay-off is high relative to the value of the last period pay-off. This will induce the seller to set a high price in the first period, whereas in the last period, when the value of the pay-off is less worth, she will set a low price, and thus increase the probability for agreement. With low time costs it is not so important when agreement and thus realisation of the pay-off takes place, and the price in the two periods will be more equal.

Under intervention this trade-off gets an extra dimension through the strategic action between the seller and the Government. When the seller acts as a Stackelberg leader setting a high price in period one, as would be rational when time costs are high, implies a high cut-off value. This, in turn, implies that the subsidy in the last period will be low, as the subsidy is negatively correlated with the cut-off value. With a low subsidy in the last period the seller is prevented from setting a high price, because combined with a low subsidy a high price will result in a low (not to say negative) probability for trade in this period. Hence, the dynamic trade off in the original model without intervention is strengthened when taking into account intervention. Setting a low price in the first period, as would be rational when time costs are low, implies a low cut-off value. This, in turn, results in a high subsidy in the last period. Then the seller can set a high price in the last period without jeopardizing the probability for agreement.

When the seller acts as a Stackelberg follower a high subsidy in the first period will imply a low cut-off value and a high price in this period. A low cut off value will, in isolation, imply a low price in the last period. On the other hand, a low cut-off value implies a high subsidy in the last period, which in turn allows a high seller's price. Hence, there are two effects on the seller's price in the last period, which draw in opposite directions. It can be shown that when the seller is the Stackelberg follower the seller's price always decreases over time, which means that the direct effect from the cut-off value offsets the indirect effect via the subsidy in the last period.

The Government, being the Stackelberg leader, faces another choice. The subsidy is negatively correlated with the cut-off value, and this is the case in both periods. Hence, choosing a low subsidy in the first period implies that the cut-off value is high, which in turn results in a low subsidy in the second period. Correspondingly, a high subsidy in the first period implies a low cut-off value and a high second period subsidy. On one hand a high cut-off value will imply a low probability for trade in the first period. Hence, the trade-off the Government faces is between a low subsidy which implies a high cut-off value and low probability for trade in the first period, or a high subsidy implying a low cut-off value and a high probability for trade. With low time costs the last period is as significant as the first. Then there is no rush to achieve an agreement and the optimal strategy may well be to choose the low-subsidy path, in which the subsidy may decrease over time. With high time costs an agreement in an early period is important, and thus the high-subsidy path, implying a low cut-off value, will be more attractive. Taking into account the seller's response, a high subsidy implies a high price in both periods, but a low cut-off value. Hence, choosing a high-subsidy path will imply high prices. We have already shown that under high time costs the seller will start out with a high price. We also showed that when the seller is the follower the direct effect on the second period price, via the cut-off value, offsets the indirect effect, via the subsidy, and thus the last period price will be low(er) due to a low cut-off value. Correspondingly will the low-subsidy path imply low prices. This is true in the first period, but in the last period the direct effect, via a high cut-off value, will dominate and thus the seller will not set the price as low as would be the case when solely reacting to the subsidy.

When the Government acts as a Stackelberg follower, a high price in the first period will imply that she reacts with a high subsidy. This, however, also results in a high cut-off value. This will have two opposite effects on the subsidy in the last period. The high cut-off value will have a direct, negative effect on the last period subsidy, whereas it has a positive effect on the seller's price, which in turn has an indirect, positive effect on the subsidy. It can be shown that the subsidy always increases over time when the Government acts as a Stackelberg follower, and thus that the indirect effect, through the seller's price offsets the direct effect of the cut-off value.

The differences in the time path for the subsidy and the seller's price in the two formulations of the game is visualised in figure 1 and 2.

Figure 1 *Equilibrium output for the price and the subsidy in a durable good monopoly with intervention and when the Government is the Stackelberg leader, patient agents (δ=0.9) to the left and impatient agents (δ=0.1) to the right. C=0.6, W=0.4 (Case A)*

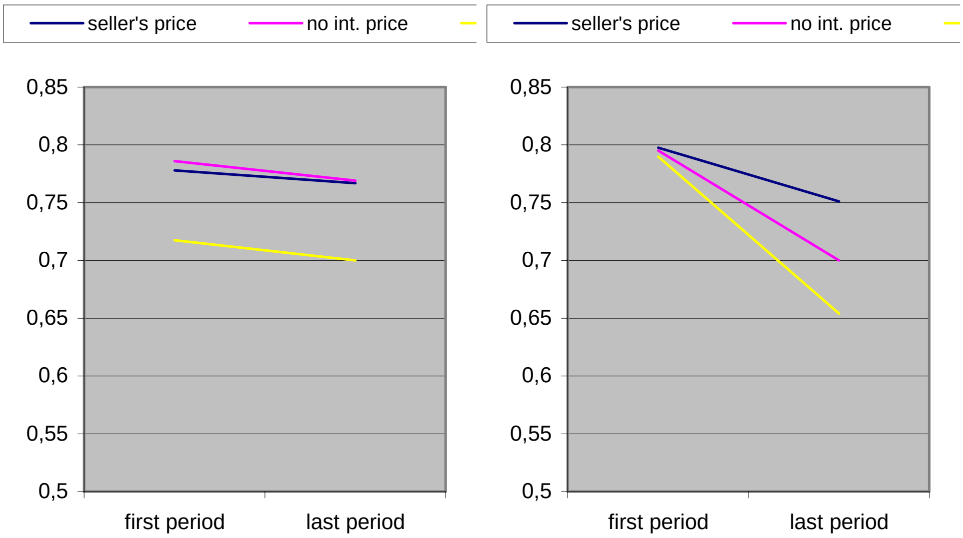
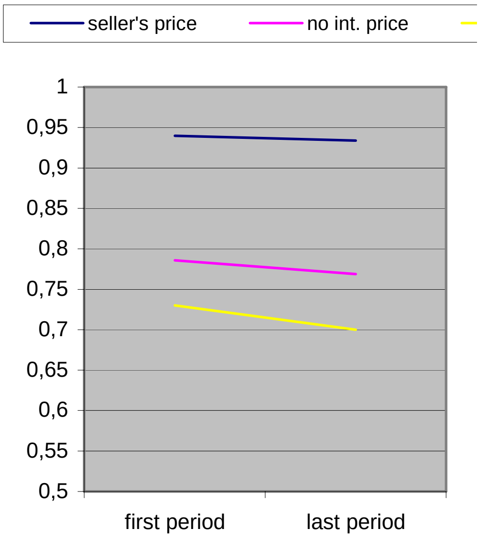
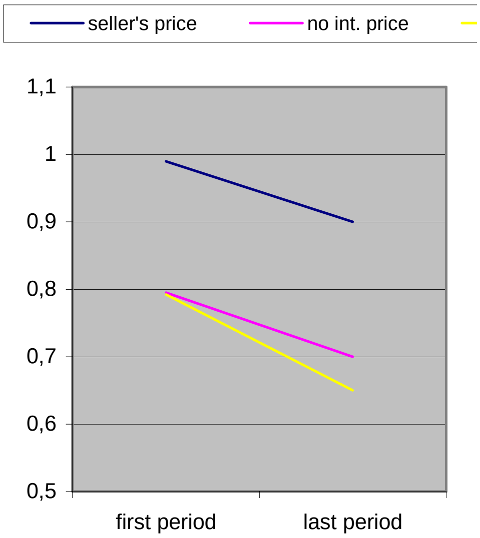


Figure 2 *Equilibrium output for the price and the subsidy in a durable good monopoly with intervention and when the seller is the Stackelberg leader, patient agents (δ=0.9) to the left and impatient agents (δ=0.1) to the right. C=0.6, W=0.4 (Case B)*





The figures exhibit one feature of special interest. When time costs are low and the Government acts as a Stackelberg leader the price the seller offers is lower under intervention compared to no intervention. This somewhat counterintuitive result is due to the fact that the seller’s price in the first period is positively correlated with the subsidy. The subsidy is negatively correlated with the cut-off value in both periods. With low time costs it is not so important to get a sale in the first period and thus it is not crucial to have a low cut-off value. Hence, the Government trades off a high subsidy and low cut-off value in the first period for a lower subsidy and higher cut-off value. A low subsidy in turn “forces” the seller to set a low price in this period. As a low subsidy in period one implies a low subsidy in period two (the low subsidy path), the seller is “forces” to choose a low price also in the last period. This effect may be seen as a kind of Government’s “disciplining” of the seller. When time costs are high, the Government’s trade of is such that it is preferable to set a high subsidy and thus a low cut-off value in the first period. Then the seller can set a price, which is higher than it would have been without intervention.

3.2 Comparing the two formulations of the intervention

The effects of the intervention on the equilibrium variables differ in the two formulations of the game between the seller and the Government. When the Government is the Stackelberg leader both the subsidy and the seller's price are lower compared to when the seller is the leader. This is valid in both periods, and it is independent of the size of the time costs. There is no distinct difference in the net price when the seller or the Government acts as a Stackelberg leader.

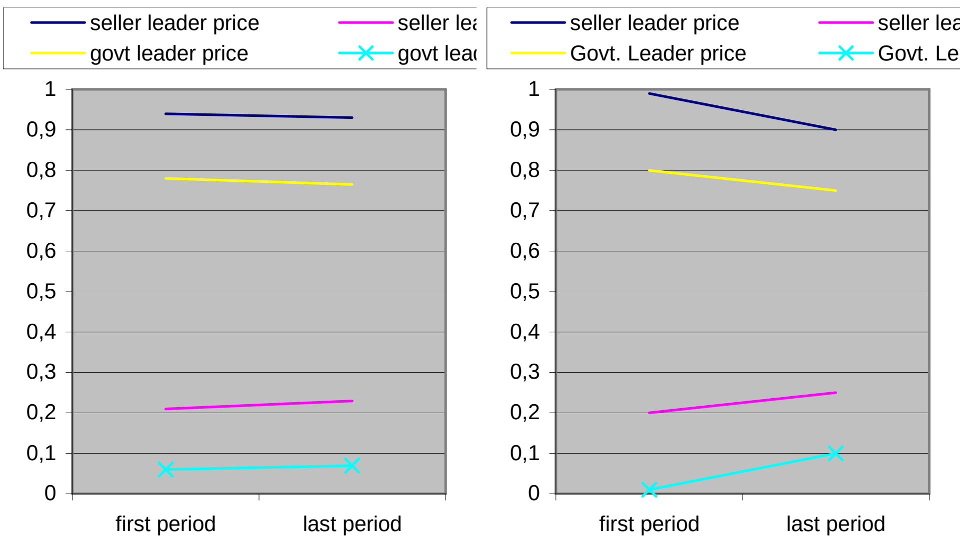
For a given set of reservation values (W and C) and fixed time costs it is more likely that intervention takes place when the seller acts as the Stackelberg leader compared to if the Government acts as the leader. This is intuitive, as it is the Government who has to take the costs of intervention by paying the subsidy, whereas both agents (seller and Government) enjoys the positive effects by increased probability for trade.

Independent of which of the seller or the Government acts as a Stackelberg leader, for given time costs and reservation values the equilibrium cut-off value and final net price are the same. However, as the condition for intervention is different in the two formulations of the intervention game, intervention has different effects depending on who acts as a Stackelberg leader. When the Government acts as a Stackelberg leader an intervention will always speed up the negotiation process and reduce the equilibrium inefficiency. On the other hand, when the seller acts as a Stackelberg leader intervention does not automatically lead to quicker negotiations and ex ante more efficient results. The reason is that even for very low reservation prices there may be a positive subsidy when the seller acts as a Stackelberg leader. But, the subsidy offered by very low reservation values is not sufficient to offset the increase in price and thus cut-off value due to intervention, and hence both the cut-off value and the final price is higher than would be the case without intervention.

On the other end of the scale we find an equilibrium solution in which not only the net price is lower than the no-intervention price, but also the seller's price before the subsidy is deducted. This situation occurs when the Government acts as a Stackelberg leader and the time costs are high, and it was shown and explained in figure 1.

Figure 3 shows the difference in price and subsidy under different leadership in the intervention game and for varying time costs. The reservation values are kept constant.

Figure 3 *Seller's price and subsidy under different formulations of the intervention game. Low time costs (δ = 0.9) left, and high time costs (δ = 0.1) right. C=0.6, W=0,4*



4 Empirical examples

In the last part of the 1970s the Norwegian government over a period of years took part in the central negotiations between the central trade union and employers' organisation and the farmer's central organisation. The Government offered different types of subsidies (a general tax relief, subsidies to basic consumer goods and a relief in the employers' contribution to the pension system) if the solution of the negotiations resulted in a moderate wage increase. The main motivation was to stop an accelerating spiral of inflation, increased living costs and increased wages. A more recent example is the "inclusive working-life" programme. Due to the fact that an increasing rate of the work-force received disability benefits the Norwegian government intervened in the negotiations between the central trade union and employers' organisation and offered subsidies, in the form of a wage-subsidy to less efficient workers and tax relief to firms employing such workers, if workers wit reduced working abilities were kept employed.

In both the above cases the good sold is labour, and the private agents negotiate about the price of labour (wage rate) and other conditions for trading this good. It is well known from the labour market literature that employment is a function of the wage rate. The Government intervened with a subsidy in order to either affect the size of the wage rate directly, or the employment of specific groups of the workforce. We assume that the trade union, representing the employees, is the seller (of labour) and employers' organisation, representing private firms, is the buyer. Results from the analysis it is crucial whether the Government "takes a lead" towards the trade union in the negotiations or whether it "adjusts" to the trade union's strategy. In the former case the Government will be more reluctant to intervene and it will offer a smaller compensation in the case of intervention. Given intervention, however, there is a high probability that this will speed up the negotiations and reduce the probability for no agreement when agreement is efficient (equilibrium inefficiency). If the time is not important (low time costs) and the valuation of agreement (reservation values) is relatively low the intervention will speed up negotiations more compared to if the Government adjusted to the trade union's strategy. On the other hand it will not reduce the probability for failing to reach agreement as much as would have been the case if the Government adjusted to the trade unions strategy. If the time is important an intervention will speed up the negotiations more and reduce the probability for failing to reach an agreement more if the Government adjusts to the trade union's strategy.

5 Conclusions

There are several examples of public intervention in negotiations between private agents. The crucial question is to what degree such interventions may contribute to speed up the negotiation process and increase the ex ante efficiency of the outcome?

The answer to these questions depends on the formulation of the negotiation process, the time costs of the agents and the reservation values.

The point of departure for the analysis in this paper is a traditional durable goods monopoly model. Then we introduce a third agent, Government, which has a positive valuation of agreement and has the ability to offer compensation to the trading agents if agreement is reached. If the Government acts as a Stackelberg leader towards the seller it will be more reluctant to intervene and offer a lower subsidy compared to if it acts as a Stackelberg follower and the seller is the leader.

On the other hand, when the Government acts as a Stackelberg leader towards the seller in the intervention game intervention will always speed up the negotiations and reduce the equilibrium inefficiency. Government leadership will also “discipline” the seller so that the seller’s price is lower compared to if the seller acts as a Stackelberg leader.

If the seller acts as a Stackelberg leader both seller’s price path and the subsidy path will be higher. The final net price, however, is the same.

These results may be of interest e.g. for Governments when intervening in the centralised wage negotiations. Defining the trade union as the seller, taking a leadership in the negotiations will limit the costs of the intervention, and with certainty speed up the negotiation process and reduce equilibrium inefficiency.

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Appendix

Proof of proposition 1

In the last period the seller, being the follower in a Stackelberg game where the Government is the leader, faces the following maximisation problem $\max_{p1A}\left[(p_{1A}-C)(T-p_{1A}+x_{1A})\right]$, which gives the following reaction function

$$p_{1A}{}^{R}=\frac{x_{1A}+W+T}{2} \tag{A1}$$

The optimal subsidy for the Government to set in the last period, given that the seller sets the price p_{1A}, is given by $\max_{x1A}\left[(W-x_{1A})(T-p_{1A}+x_{1A})\right]$. Substituting for p_{1A} by $p_{1A}{}^{R}$ and solving this optimisation problem gives (4A). Inserting for (4A) in (A1) gives (5A).

In the last period the Government, being the follower in a Stackelberg game with the seller, faces the following maximisation problem $\max_{x1B}\left[(W-x_{1B})(T-p_{1B}+x_{1B})\right]$, which gives the following reaction function

$$x_{1B}{}^{R}=\frac{p_{1B}+W-T}{2} \tag{A2}$$

The optimal price for the seller to set in the last period, given that the Government sets the subsidy, x_{1A}, is given by $\max_{p1B}\left[(p_{1B}-C)(T-p_{BA}+x_{1B})\right]$. Substituting for x_{1B} by $x_{1B}{}^{R}$ and solving this optimisation problem gives (4B). Inserting for (4B) in (A2) gives (5B).

In the first period the seller sets the optimal price by first fixing a cut-off value and then decides the optimal price by (8). This is done by maximising the continuation pay-off in (10) when having inserted for the last period equilibrium expressions and substituted p_{2A} by (8). This leads to the following expression for the seller's continuation pay-off:

$$U_{sA}(W,C,\delta)=\max_T\left[(1-\frac{\delta}{4})(T-C)-\frac{\delta}{4}W+x_{2A})(1-T)+\delta\left(\frac{T+W-C}{4}\right)^2\right] \qquad \text{(A3)}$$

Maximising (A3) with respect to *T*, and then inserting for T_A^R in (8) gives the optimal cut-off value and price, both as reactions to the subsidy in this period:

$$T_A^R=\frac{1-\frac{\delta}{4}+C(1-\frac{3\delta}{8})+\frac{3\delta}{8}W-x_{2A}}{2-\frac{5\delta}{8}} \qquad \text{(A4)}$$

$$p_{2A}^R=\frac{(1-\frac{\delta}{4})2}{(2-\frac{5\delta}{8})}+C\left(\frac{\delta}{4}+\frac{(1-\frac{3\delta}{8})(1-\frac{\delta}{4})}{(2-\frac{5\delta}{8})}\right)+W\left(-\frac{\delta}{4}+\frac{\frac{3\delta}{8}(1-\frac{\delta}{4})}{(2-\frac{5\delta}{8})}\right)+x_{2A}\left(1-\frac{1-\frac{\delta}{4}}{2-\frac{5\delta}{8}}\right)$$

(A5)

The Government's continuation pay-off, when inserting for the last period equilibrium variables and the cut-off value, as a reaction to the subsidy, is given as

$$U_{GA}=\max x_{2A}\left[(W-x_{2A})(\frac{(1-\frac{3\delta}{8})(1-C)-\frac{3\delta}{8}W+x_{2A}}{(2-\frac{5\delta}{8})})+\frac{\delta}{8}\left(\frac{(1-\frac{\delta}{4})(1-C)+(2-\frac{\delta}{4})W-x_{2A}}{(2-\frac{5\delta}{8})}\right)^2\right]$$

(A6)

The Government maximises its continuation pay-off with respect to x_{2A} and taking into consideration the seller's prising strategy (optimal cut-off value). This gives the set of equilibrium variables as given by (12)-(15). The parameter expressions in (12)-(15) are given below:

$$f_{2A} = \frac{-8 + \frac{9\delta}{2} - \frac{11\delta^2}{16}}{16 - 6\delta}$$

$$g_{2A} = \frac{8 - \frac{3\delta}{2} - \frac{11\delta^2}{16}}{16 - 6\delta} \qquad \text{(A7)}$$

$$h_{2A} = \frac{8 - \frac{9\delta}{2} + \frac{11\delta^2}{16}}{16 - 6\delta}$$

$$a_{2A} = \frac{(1-\frac{\delta}{4})^2}{(2-\frac{5\delta}{8})} \frac{(1-\frac{3\delta}{8})(8-\frac{9\delta}{2}+\frac{11\delta^2}{16})}{(16-6\delta)(2-\frac{5\delta}{8})},$$

$$b_{2A} = -\frac{\delta}{4} + \frac{\frac{3\delta}{8}(1-\frac{\delta}{4})}{(2-\frac{5\delta}{8})} + \frac{(1-\frac{3\delta}{8})(8-\frac{3\delta}{2}-\frac{11\delta^2}{16})}{(16-6\delta)(2-\frac{5\delta}{8})} \qquad \text{(A8)}$$

$$d_{2A} = \frac{\delta}{4} + \frac{(1-\frac{3\delta}{8})(1-\frac{\delta}{4})}{(2-\frac{5\delta}{8})} + \frac{(1-\frac{3\delta}{8})(8-\frac{9\delta}{2}+\frac{11\delta^2}{16})}{(16-6\delta)(2-\frac{5\delta}{8})}$$

$$k_{2A} = \frac{(1-\frac{\delta}{4})^2}{(2-\frac{5\delta}{8})} + \frac{(1-\frac{3\delta}{8})(8-\frac{9\delta}{2}+\frac{11\delta^2}{16})}{(16-6\delta)(2-\frac{5\delta}{8})} + \frac{(8-\frac{9\delta}{2}+\frac{11\delta^2}{16})}{(16-6\delta)}$$

$$m_{2A} = -\frac{\delta}{4} + \frac{\frac{3\delta}{8}(1-\frac{\delta}{4})}{(2-\frac{5\delta}{8})} + \frac{(1-\frac{\delta}{4})(8-\frac{3\delta}{2}-\frac{11\delta^2}{16})}{(16-6\delta)(2-\frac{5\delta}{8})} - \frac{(8-\frac{3\delta}{2}-\frac{11\delta^2}{16})}{(16-6\delta)} \qquad \text{(A9)}$$

$$s_{2A} = \frac{\delta}{4} + \frac{(1-\frac{3\delta}{8})(1-\frac{\delta}{4})}{(2-\frac{5\delta}{8})} + \frac{(1-\frac{\delta}{4})(8-\frac{9\delta}{2}+\frac{11\delta^2}{16})}{(16-6\delta)(2-\frac{5\delta}{8})} - \frac{(8-\frac{9\delta}{2}+\frac{11\delta^2}{16})}{(16-6\delta)}$$

$$t_{2A} = \frac{24 - \frac{29\delta}{2} + \frac{35\delta^2}{16}}{(2 - \frac{5\delta}{8})(16 - 6\delta)}$$

$$y_{2A} = \frac{-8 + \frac{15\delta}{2} - \frac{25\delta^2}{16}}{(2 - \frac{5\delta}{8})(16 - 6\delta)} \qquad \text{(A10)}$$

$$z_{2A} = \frac{8 - \frac{15\delta}{2} + \frac{25\delta^2}{16}}{(2 - \frac{5\delta}{8})(16 - 6\delta)}$$

Inserting for T_A* in (A2)-(A4) gives the last period equilibrium variables as given by (4A), (5A) and (6) in section 2, and with the following parameters:

$$a_{1A} = \frac{(24 - \frac{29\delta}{2} + \frac{25\delta^2}{16})}{4(16 - 6\delta)(2 - \frac{5\delta}{8})},$$

$$b_{1A} = \frac{1}{4} - \frac{(8 - \frac{15\delta}{2} + \frac{25\delta^2}{16})}{4(16 - 6\delta)(2 - \frac{5\delta}{8})} \qquad \text{(A11)}$$

$$d_{1A} = \frac{3}{4} + \frac{(8 - \frac{15\delta}{2} + \frac{25\delta^2}{16})}{4(16 - 6\delta)(2 - \frac{5\delta}{8})}$$

$$f_{1B} = -\frac{(24 - \frac{29\delta}{2} + \frac{35\delta^2}{16})}{2(16 - 6\delta)(2 - \frac{5\delta}{8})}$$

$$g_{1A} = \frac{1}{2} + \frac{(8 - \frac{15\delta}{2} + \frac{25\delta^2}{16})}{2(16 - 6\delta)(2 - \frac{5\delta}{8})} \qquad \text{(A12)}$$

$$h_{1A} = \frac{1}{2} - \frac{(8 - \frac{15\delta}{2} + \frac{25\delta^2}{16})}{2(16 - 6\delta)(2 - \frac{5\delta}{8})}$$

$$k_{1A} = \frac{3(24 - \frac{29\delta}{2} + \frac{35\delta^2}{16})}{4(16-6\delta)(2-\frac{5\delta}{8})},$$

$$m_{1A} = -\frac{1}{4} + \frac{3(-8 + \frac{15\delta}{2} + \frac{25\delta^2}{16})}{4(16-6\delta)(2-\frac{5\delta}{8})} \qquad \text{(A13)}$$

$$s_{1A} = \frac{1}{4} + \frac{3(8 - \frac{15\delta}{2} + \frac{25\delta^2}{16})}{4(16-6\delta)(2-\frac{5\delta}{8})}$$

When the seller acts as the Stackelberg leader the Government in the first period sets the optimal subsidy by first fixing a cut-off value and then decides the optimal subsidy by (9). This is done by maximising the continuation pay-off in (11) when having inserted for the last period equilibrium expressions and substituted x_{2B} by (9). This leads to the following expression for the Government's continuation pay-off:

$$U_{GB}(W,C,\delta) = \max_T \left[(1-\frac{\delta}{4})(W+T) + \frac{\delta}{4}C - p_{2B})(1-T) + \delta\left(\frac{T+W-C}{4}\right)^2 \right] \qquad \text{(A14)}$$

Maximising (A14) with respect to T, and then inserting for T_B^R in (9) gives the optimal cut-off value and subsidy, both as reactions to the subsidy in this period:

$$T_B^{\ R} = \frac{1 - \frac{\delta}{4} + W(-1 + \frac{3\delta}{8}) - \frac{3\delta}{8}C + p_{1B}}{2 - \frac{5\delta}{8}} \qquad \text{(A15)}$$

$$x_{2B}^{\ R} = p_{2B}\left(1 - \frac{1-\frac{\delta}{4}}{2-\frac{5\delta}{8}}\right) + W\left(\frac{\delta}{4} - \frac{(1-\frac{\delta}{4})(-1+\frac{3\delta}{8})}{2-\frac{5\delta}{8}}\right) + C\left(-\frac{\delta}{4} + \frac{(1-\frac{\delta}{4})\frac{3\delta}{8}}{2-\frac{5\delta}{8}}\right) - \frac{(1-\frac{\delta}{4})^2}{2-\frac{5\delta}{8}}$$

(A16)

The seller's continuation pay-off, when inserting for the last period equilibrium variables and the cut-off value, as a reaction to the subsidy, is given as

$$U_{sB} = \max_{p_{2B}} \left[(p_{2B} - C)\left(\frac{(1-\frac{3\delta}{8})(1+W) + \frac{3\delta}{8}C - p_{2B}}{(2-\frac{5\delta}{8})}\right) + \frac{\delta}{8}\left(\frac{(1-\frac{\delta}{4})(1+W) - (2-\frac{\delta}{4})C + p_{2B}}{(2-\frac{5\delta}{8})}\right)^2 \right] \quad \text{(A17)}$$

The seller maximises its continuation pay-off with respect to p_{2B} and taking into consideration the Government's subsidisation strategy (optimal cut-off value). This gives the set of equilibrium variables as given by (16)-(19). The parameter expressions in (16)-(19) are given below:

$$a_{2B} = \frac{8 - \frac{9\delta}{2} + \frac{11\delta}{16}}{16 - 6\delta}$$

$$b_{2B} = \frac{(8 - \frac{9\delta}{2} + \frac{11\delta^2}{16})}{16 - 6\delta} \quad \text{(A18)}$$

$$d_{2B} = \frac{(8 - \frac{3\delta}{2} - \frac{11\delta^2}{16})}{16 - 6\delta}$$

$$f_{2B} = \frac{-(1-\frac{\delta}{4})^2}{(2-\frac{5\delta}{8})} + \frac{(1-\frac{3\delta}{8})(8 - \frac{9\delta}{2} + \frac{11\delta^2}{16})}{(2-\frac{5\delta}{8})(16-6\delta)}$$

$$g_{2B} = \frac{\delta}{4} + \frac{(1-\frac{\delta}{4})(1-\frac{3\delta}{8})}{(2-\frac{5\delta}{8})} + \frac{(1-\frac{3\delta}{8})(8 - \frac{9\delta}{2} + \frac{11\delta^2}{16})}{(2-\frac{5\delta}{8})(16-6\delta)} \quad \text{(A19)}$$

$$h_{2B} = -\frac{\delta}{4} + \frac{(1-\frac{3\delta}{8})(8 - \frac{3\delta}{2} - \frac{11\delta^2}{16})}{(2-\frac{5\delta}{8})(16-6\delta)} + \frac{\frac{3\delta}{8}(1-\frac{\delta}{4})}{2-\frac{5\delta}{8})}$$

$$t_B = \frac{24 - \frac{29\delta}{2} + \frac{35\delta^2}{16}}{(2 - \frac{5\delta}{8})(16 - 6\delta)}$$

$$y_B = \frac{-8 + \frac{15\delta}{2} - \frac{25\delta^2}{16}}{(2 - \frac{5\delta}{8})(16 - 6\delta)} \qquad \text{(A20)}$$

$$z_B = \frac{8 - \frac{15\delta}{2} + \frac{25\delta^2}{16}}{(2 - \frac{5\delta}{8})(16 - 6\delta)}$$

$$k_{2B} = \frac{(8 - \frac{3\delta}{2} + \frac{11\delta^2}{16})}{(16 - 6\delta)} + \frac{(1 - \frac{\delta}{4})^2}{(2 - \frac{5\delta}{8})} - \frac{(8 - \frac{3\delta}{2} + \frac{11\delta^2}{16})(1 - \frac{3\delta}{8})}{(16 - 6\delta)(2 - \frac{5\delta}{8})}$$

$$m_{2B} = -\frac{\delta}{4} + (\frac{(8 - \frac{9\delta}{2} + \frac{11\delta^2}{16})}{(16 - 6\delta)} - \frac{(1 - \frac{3\delta}{8})(8 - \frac{9\delta}{2} + \frac{11\delta^2}{16})}{(2 - \frac{5\delta}{8})(16 - 6\delta)} - \frac{(1 - \frac{3\delta}{8})(1 - \frac{\delta}{4})}{2 - \frac{5\delta}{8}} \qquad \text{(A21)}$$

$$s_{2B} = \frac{\delta}{4} + \frac{(8 - \frac{3\delta}{2} - \frac{11\delta^2}{16})}{(16 - 6\delta)} - \frac{\frac{3\delta}{8}(1 - \frac{\delta}{4})}{2 - \frac{5\delta}{8}} - \frac{(8 - \frac{3\delta}{2} - \frac{11\delta^2}{16})(1 - \frac{3\delta}{8})}{(2 - \frac{5\delta}{8})(16 - 6\delta)}$$

Inserting for T_B* in the last period equilibrium solutions, given by (4B), (5B) and (6) gives the following parameters:

$$a_{1B} = \frac{24 - \frac{29\delta}{2} + \frac{35\delta 2}{16}}{2(16-6\delta)(2-\frac{5\delta}{8})}$$

$$b_{1B} = \frac{1}{2} - \frac{8 - \frac{15\delta}{2} + \frac{25\delta^2}{16}}{2(2-\frac{2\delta}{8})(16-6\delta)}, \tag{A22}$$

$$d_{1B} = \frac{1}{2} + \frac{8 - \frac{15\delta}{2} + \frac{25\delta^2}{16}}{2(2-\frac{2\delta}{8})(16-6\delta)}$$

$$f_{1B} = -\frac{24 - \frac{293\delta}{2} + \frac{35\delta^2}{16}}{4(16-6\delta)(2-\frac{2\delta}{8})}$$

$$g_{1B} = \frac{3}{4} + \frac{8 - \frac{15\delta}{2} + \frac{25\delta^2}{16}}{4(2-\frac{2\delta}{8})(16-6\delta)} \tag{A23}$$

$$h_{1B} = \frac{1}{4} - \frac{8 - \frac{15\delta}{2} + \frac{25\delta^2}{16}}{4(2-\frac{2\delta}{8})(16-6\delta)}$$

$$k_{1B} = \frac{3(24 - \frac{29\delta}{2} + \frac{25\delta^2}{16})}{4(16-6\delta)(2-\frac{5\delta}{8})}$$

$$m_{1B} = -\frac{1}{4} + \frac{3(-8 + \frac{15\delta}{2} - \frac{25\delta^2}{16})}{4(2-\frac{5\delta}{8})(16-6\delta)} \tag{A24}$$

$$s_{1B} = \frac{1}{4} + \frac{3(8 - \frac{15\delta}{2} + \frac{25\delta^2}{16})}{4(2-\frac{5\delta}{8})(16-6\delta)}$$

Proof of proposition 2

The condition for $p_{2B}* > p_{2A}*$ is

$$W\left(\frac{\delta}{4}+\frac{(8-\frac{9\delta}{2}+\frac{11\delta^2}{16}}{(16-6\delta)}-\frac{\frac{3\delta}{8}(1-\frac{\delta}{4})}{(2-\frac{5\delta}{8})}-\frac{(1-\frac{3\delta}{8})(8-\frac{3\delta}{2}-\frac{11\delta 2}{16}}{(16-6\delta)(2-\frac{5\delta}{8})}\right)+$$
$$C\left(-\frac{\delta}{4}+\frac{(8-\frac{3\delta}{2}-\frac{11\delta^2}{16})}{(16-6\delta)}-\frac{(1-\frac{3\delta}{8})(1-\frac{\delta}{4})}{(2-\frac{5\delta}{8})}-\frac{(1-\frac{3\delta}{8})(8-\frac{9\delta}{2}-\frac{11\delta 2}{16}}{(16-6\delta)(2-\frac{5\delta}{8})}\right)> \quad \text{(A25)}$$
$$\frac{(1-\frac{\delta}{4})2}{(2-\frac{5\delta}{8})}-\frac{(1-\frac{3\delta}{8})(8-\frac{9\delta}{2}+\frac{11\delta 2}{16})}{(16-6\delta)(2-\frac{5\delta}{8})}-\frac{(8-\frac{9\delta}{2}+\frac{11\delta^2}{16})}{(16-6\delta)}$$

The condition for $x_{2B}* > x_{2A}*$ is

$$W\left(\frac{\delta}{4}+\frac{(1-\frac{3\delta}{8})(1-\frac{\delta}{4})}{(2-\frac{5\delta}{8})}+\frac{(1-\frac{3\delta}{8})(8-\frac{9\delta}{2}+\frac{11\delta^2}{16}}{(16-6\delta)(2-\frac{5\delta}{8})}-\frac{(8-\frac{3\delta}{2}-\frac{11\delta^2}{16}}{(16-6\delta)}\right)+$$
$$C\left(-\frac{\delta}{4}+\frac{\frac{3\delta}{8}(1-\frac{\delta}{4})}{(2-\frac{5\delta}{8})}+\frac{(1-\frac{3\delta}{8})(8-\frac{3\delta}{2}-\frac{11\delta^2}{16})}{(16-6\delta)(2-\frac{5\delta}{8})}-\frac{(8-\frac{9\delta}{2}+\frac{11\delta^2}{16})}{(16-6\delta)}\right)> \quad \text{(A26)}$$
$$\frac{(1-\frac{\delta}{4})^2}{(2-\frac{5\delta}{8})}-\frac{(1-\frac{3\delta}{8})(8-\frac{9\delta}{2}+\frac{11\delta 2}{16})}{(16-6\delta)(2-\frac{5\delta}{8})}-\frac{(8-\frac{9\delta}{2}+\frac{11\delta^2}{16})}{(16-6\delta)}$$

The condition for $p_{1B}* > p_{1A}*$ is

$$W\left(\frac{1}{4}-\frac{(8-\frac{15\delta}{2}+\frac{25\delta^2}{16}}{(16-6\delta)(2-\frac{5\delta}{8})}\right)+C\left(-\frac{1}{4}+\frac{(8-\frac{15\delta}{2}+\frac{25\delta^2}{16}}{(16-6\delta)(2-\frac{5\delta}{8})}\right)>\frac{24-\frac{29\delta}{2}+\frac{35\delta 2}{16})}{(16-6\delta)(2-\frac{5\delta}{8})} \quad \text{(A27)}$$

The condition for $x_{1B}* > x_{1A}*$ is

$$W\left(-\frac{1}{4}+\frac{(8-\frac{9\delta}{2}+\frac{11\delta^2}{16}}{(16-6\delta)(2-\frac{5\delta}{8})}\right)+C\left(\frac{1}{4}-\frac{(8-\frac{15\delta}{2}+\frac{25\delta^2}{16})}{(16-6\delta)(2-\frac{5\delta}{8})}\right)>\frac{(24-\frac{29\delta}{2}+\frac{25\delta^2}{16})}{(16-6\delta)(2-\frac{5\delta}{8})} \qquad \text{(A28)}$$

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Notes

[i] In contrast, models with common knowledge about gains from trade (the gap case) exhibit a unique equilibrium, which follows the Coase conjecture

[ii] The presented equilibrium is valid for a finite horizon model. In order for the limit of this model to be an equilibrium in the infinite horizon model a further argument must be added. See e.g. Fudenberg et al (1985) for a general analysis of infinite horizon bargaining models.

[iii] Often the subsidy will be negative in the first period, but positive in the last period. Because the choice of subsidy/price in one period has consequences fort he corresponding choice in the other period, the model does not allow a solution where we assume no intervention in the first period, but intervention in the last period.

[iv] A third option is that the seller and the Government decides the price and the subsidy simultaneously, both as a reaction to the buyer's strategy and independent of each other. First, this option seems unlikely from an empirical point of view. Second, in equilibrium the two agents seller and Government does not necessarily coordinate upon the same cut-off value, and thus the equilibrium solution is not necessarily sub-game perfect.