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### Note on the open-loop von Stackelberg equilibrium in the cartel versus fringe model

Groot, F.; Withagen, C.A.A.M.; de Zeeuw, A.J.

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by  
Fons Groot, Cees Withagen  
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**Address** : Warandelaan 2, P.O. Box 90153, 5000 LE Tilburg, The Netherlands  
**Phone** : +31 13 663050  
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## NOTE ON THE OPEN-LOOP VON STACKELBERG EQUILIBRIUM IN THE CARTEL VERSUS FRINGE MODEL

*Fons Groot\*, Cees Withagen and Aart de Zeeuw*

In his remarkable article 'Oil prices, cartels and the problem of dynamic inconsistency' Newbery (1981) shows that if the supply side of the oil market can be characterised as one with a dominant cartel and a large number of small producers (called the fringe as a group) the open-loop von Stackelberg equilibrium may give rise to dynamic inconsistency, and should therefore be rejected as an appropriate equilibrium concept. Dynamic inconsistency is also found to occur by Ulph (1982) in a similar model.

The purpose of this note is not to dispute the validity of this result nor its relevance. What we wish to show is that the derivation of the equilibrium is not correct. Apart from the fact that the correct derivation yields qualitatively as well as quantitatively different equilibrium trajectories (although the main conclusion still stands), there is some additional value in the present paper because one of the objectives in Newbery's article was 'to demonstrate a method of analysis which makes the solution of quite complex problems ... accessible to mathematically unsophisticated economists' (p. 619). It is furthermore argued by Newbery that 'This approach also provides scope for intuition so that the mathematically sophisticated can check the plausibility of their solutions, or, given various possible solutions, can choose the correct one' (p. 619). The conclusion of the present note is, however, that in the case at hand intuition is not performing as an entirely reliable guide.

### I. THE PROBLEM

Let the world demand schedule of oil be given by

$$x = \bar{p} - p,$$

where  $x$  denotes demand,  $p$  is the market price and  $\bar{p}$  is a choke price. Demand is met by a coherent cartel with constant per unit extraction costs  $k^c$ , having an initial endowment of oil amounting to  $S_0^c$ , and a large number of identical small suppliers, each with constant per unit extraction costs  $k^f$  and aggregate initial resources  $S_0^f$ . The common discount rate is denoted by  $r$ , a positive constant. In order to have an interesting problem it will be assumed that  $\bar{p} > \max(k^c, k^f)$ . Each individual fringe member takes the market price as given<sup>1</sup> and maximises

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<sup>1</sup> It would be more elegant to start with a finite number of fringe members and then to see what happens to the equilibrium if that number goes to infinity. It can be shown that indeed price taking behaviour results. We follow Newbery and Ulph who assume price taking behaviour from the outset.

its total discounted profits. The cartel has the same objective and takes the reaction of the fringe into account in determining the optimal extraction path. Let  $E^f$  be the equilibrium aggregate extraction trajectory of the fringe and  $E^c$  be the extraction trajectory of the cartel.

Then  $E^f$  maximises

$$\int_0^{\infty} e^{-rt} (p - k^f) E^f dt,$$

subject to

$$\dot{S}^f = -E^f, \quad S^f(0) = S_0^f,$$

$$E^f \geq 0, \quad S^f \geq 0.$$

The time argument is omitted wherever there can be no confusion. It is straightforward to see that we have as necessary conditions

$$h_1 := k^f + \lambda^f e^{rt} - p \geq 0,$$

$$E^f h_1 = 0,$$

where  $\lambda^f (> 0)$  is the constant shadow price of the aggregate in situ oil stocks of the fringe. Since the objective functionals of the fringe members are concave, a trajectory satisfying the necessary conditions is optimal, if  $\lambda^f S^f$  approaches zero as  $t$  goes to infinity.

The way Newbery and Ulph proceed is then to analyse the optimal strategy of the cartel by ruling out possible sequences of regimes, not using optimal control theory. In contrast, we argue that control theory is a valuable tool in analysing the cartel's problem, be it that no standard theorems can be invoked. We will show that the proper analysis with optimal control theory gives somewhat different results.

The problem of the cartel can be formulated as follows.

$$\max_{E^c, E^f} \int_0^{\infty} e^{-rt} [\bar{p} - E^c - E^f - k^c] E^c dt,$$

subject to

$$h_1 = k^f + \lambda^f e^{rt} - (\bar{p} - E^c - E^f) \geq 0,$$

$$E^f h_1 = 0,$$

$$\dot{S}^f = -E^f, \quad S^f \geq 0, \quad E^f \geq 0, \quad S^f(0) = S_0^f, \quad \lim_{t \rightarrow \infty} S^f(t) = 0,$$

$$\dot{S}^c = -E^c, \quad S^c \geq 0, \quad E^c \geq 0, \quad S^c(0) = S_0^c,$$

$$\dot{\lambda}^f = 0, \quad \lambda^f \geq 0.$$

So the cartel chooses not only its own extraction trajectory but the fringe's as well, subject to the condition that each fringe member is a price taking profit maximiser. The cartel also takes care that the market is always in equilibrium ( $x = E^f + E^c$  is therefore inserted into the demand function).

This optimal control problem does not allow for a standard application of the Pontryagin maximum principle because in general the constraint qualification does not hold. However, Neustadt (1976) gives necessary

conditions for optimality in this case. We follow Seierstadt and Sydsæter (1987), who provide a useful formulation. It would go too far to outline all the differences with the standard necessary conditions. In general, the co-state variables need no longer be continuous and the multiplier functions associated with the constraints are not necessarily piece-wise continuous. What remains however, and this is important in the present context, is that the Hamiltonian is maximised with respect to the control variables. The Hamiltonian reads

$$H^c := e^{-rt} [\bar{p} - E^c - E^f - k^c] E^c - \lambda_1^c E^c - \lambda_2^c E^f.$$

Note that, since  $\dot{\lambda}^f = 0$ , the corresponding co-state variable does not appear in the Hamiltonian. Furthermore, it is evident that the co-state variables  $\lambda_1^c$  and  $\lambda_2^c$ , denoting the value the cartel attaches to a marginal increase in its own initial stock and the fringe's initial stock respectively, will be constants. Hence, although the co-states  $\lambda_1^c$  and  $\lambda_2^c$  need not be continuous in general, they are in the present problem. Along the lines set out by Ulph and Folie (1980) we define the auxiliary prices

$$\begin{aligned} P^1 &= k^f + \lambda^f e^{rt}, \\ P^2 &= k^c + (\lambda_1^c - \lambda_2^c) e^{rt}, \\ P^3 &= \frac{1}{2}(\bar{p} + k^c) + \frac{1}{2}\lambda_1^c e^{rt}. \end{aligned}$$

For reasons that will be clear  $P^1$  is called the competitive price and  $P^3$  is called the monopoly price.  $P^2$  can be interpreted as the marginal costs the cartel incurs when it supplies at the competitive price.  $P^2$  consists of the marginal extraction costs  $k^c$ , the opportunity costs  $\lambda_1^c e^{rt}$  of extracting its own resource now rather than in the future and the costs  $-\lambda_2^c e^{rt}$  the cartel incurs by the fact that producing an additional amount now will cause a higher stock of the fringe ( $\lambda_2^c$  is of course negative). Suppose that it is optimal to have an interval of time with  $h_1 = 0$ . Then, along this interval of time,

$$H^c := e^{-rt} (P^1 - P^2) E^c - \lambda_2^c (\bar{p} - P^1),$$

is maximised subject to

$$0 \leq E^c \leq \bar{p} - P^1,$$

as can be seen from simple substitution.

If it is optimal to have an interval of time with  $h_1 > 0$  then, along this interval of time, the cartel maximises

$$H^c := e^{-rt} [2(\bar{p} - P^3) - E^c] E^c$$

subject to

$$E^c \geq 0.$$

This is so because if  $h_1 > 0$  we have  $E^f = 0$  and  $P^1 > \bar{p}$ . The following is now obvious.

#### THEOREM

(a) Suppose it is optimal for the cartel to have  $h_1 = 0$ . Then

$$\text{if } P^1 > P^2 \text{ then } E^c = \max(\bar{p} - P^1, 0), \quad E^f = 0 \quad (a1)$$

$$\text{if } P^2 > P^1 \text{ then } E^c = 0, \quad E^f = \max(\bar{p} - P^1, 0). \quad (a2)$$

(b) Suppose it is optimal for the cartel to have  $h_1 > 0$ . Then  $E^f = 0$ ,  $E^c = \max(\bar{p} - P^3, 0)$ .

From here the analysis can proceed in much the same way as in Newbery and Ulph. Let us concentrate on the continuity of the equilibrium price trajectory. One of the results the authors mentioned above obtain is that in the rather plausible case where the cartel has a cost advantage over the fringe, the advantage however not being extreme ( $k^c < k^f < \frac{1}{2}(\bar{p} + k^c)$ ), and where the cartel has an initial oil stock which is sufficiently large relative to the initial stock of the fringe, there will at some instant of time occur a switch from the fringe supplying at the competitive price  $P^1$  to the cartel producing at the monopoly price  $P^3$ . It can be shown along the lines set out by these authors but using our formal control theoretic setting, that this result is correct. It has also been shown by the previous authors, and can be proved to be correct, that in the case at hand the cartel will start supplying at the monopoly price  $P^3$  only after it has supplied at the competitive price  $P^1$ .

Since the optimal value of the Hamiltonian should evidently be continuous over time, a discontinuity occurs in the price trajectory at the points in time where a switch takes place from a phase with the fringe supplying to a phase with the cartel supplying at the monopoly price and vice versa. This can be seen as follows.

Along intervals of time where the cartel is the sole supplier at the monopoly price  $P^3$  the value of the Hamiltonian is

$$\hat{H}^c = e^{-rt}(\bar{p} - P^3)^2.$$

Along intervals of time where the fringe is the sole supplier at the competitive price  $P^1$  the value of the Hamiltonian is

$$\hat{H}^c = -\lambda_2^c(\bar{p} - P^1).$$

At the switch point, say  $s$ , these values should be equal implying that

$$\lambda_2^c(\bar{p} - P^1) + e^{-rs}(\bar{p} - P^3)^2 = 0.$$

But, if the price trajectory were continuous in  $s$  we would have  $P^1(s) = P^3(s)$  and hence  $P^1(s) = P^2(s) = P^3(s)$ . Now assume that at  $s$  a switch occurs from the fringe supplying to the cartel supplying at the monopoly price. As mentioned above, there should be an interval of time before  $s$  where the cartel is supplying at the competitive price. According to the theorem,  $P^1 > P^2$  along that interval, whereas just before  $s$  we have  $P^2 > P^1$ . There must therefore be an instant of time before  $s$  where  $P^1 = P^2$ . But since  $k^f \neq k^c$  the curves can intersect only once. So we obtain a contradiction.

For the cost constellation at hand the equilibrium can be depicted as in Figs 1, 2 and 3. Here the symbols  $C$  and  $C^m$  mean that the cartel is the sole supplier at the competitive price and the monopoly price respectively.  $F$  means that the fringe is the sole supplier. The location of the curves  $P^1$ ,  $P^2$  and  $P^3$  is determined by two equations for the exhaustion of the resources and a third equation for the optimal choice of the co-state variable  $\lambda^f$ . For the technical details of the derivation the reader is referred to Groot *et al.* (1990).



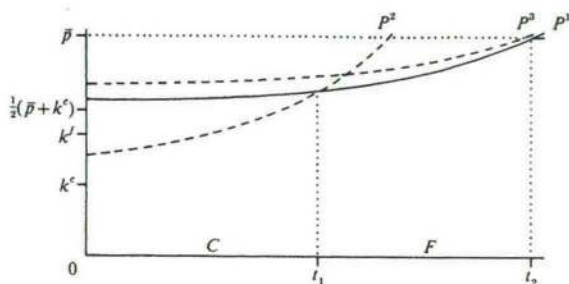
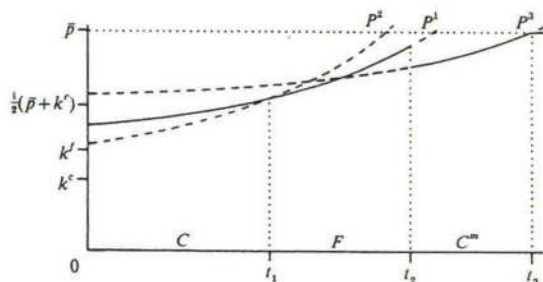
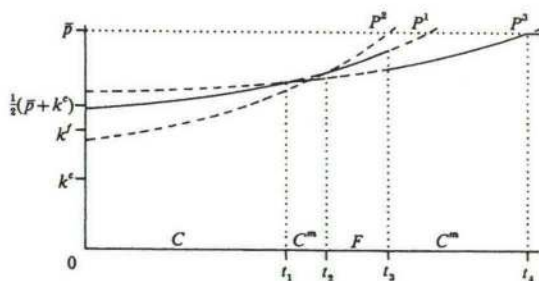
Fig. 1. Equilibrium for  $S_0^c$  'small' relative to  $S_0^f$ .

Fig. 2. Equilibrium for 'intermediate' case.

Fig. 3. Equilibrium for  $S_0^c$  'large' relative to  $S_0^f$ .

From these figures it can be seen that for more or less the same parameter values as in Newbery and Ulph the conclusion that dynamic inconsistency arises remains valid: with the parameter values we departed from there is always an initial interval of time where the cartel supplies at the competitive price. Note also that, contrary to earlier findings, there are parameter values for which there is a transition from the cartel supplying at the monopoly price to the fringe supplying, accompanied by an upward discontinuity. A numerical example can show the differences in the equilibrium trajectories obtained by us and Ulph and Newbery.

Suppose  $\bar{p} = 40$ ,  $k^f = 20$ ,  $k^c = 15$ ,  $r = 0.1$  and  $S_0^f = 15$ . For  $S_0^c = 50$  the equilibrium will be as in Fig. 2, with  $t_1 = 0.47$ ,  $t_2 = 8.1$  and  $t_3 = 11.8$ . Cartel's profits are 596.8, whereas Newbery would obtain 594.2. If, *ceteris paribus*,  $S_0^c = 150$ , then the equilibrium is as in Fig. 3, with  $t_1 = 6.2$ ,  $t_2 = 7.2$ ,  $t_3 = 9.3$  and  $t_4 = 21.4$ . In this case the cartel's profits are 1,096.4 where Newbery would obtain only 1,089.4.

An interesting question is why the intuition of the previous authors has failed to reveal the correct solution. The main reason is that it should be taken into account that the stock of the fringe has a negative shadow value to the cartel, i.e.  $\lambda_2^c$  is strictly negative. For the situation where the cartel is bound to supply at the competitive price the Hamiltonian reads

$$e^{-rt} P^1(t) E^c(t) - e^{-rt} (k^c + \lambda_1^c e^{rt} - \lambda_2^c e^{rt}) E^c(t) - \lambda_2^c [\bar{p} - P^1(t)].$$

The first term just gives the revenues. The first part of the second term are the direct production costs, the second part constitutes the opportunity costs of supplying now instead of in the future and the third part gives the price the cartel is willing to pay for a marginal increase of the stock of the fringe. If the cartel would produce one unit more, the fringe would produce one unit less and therefore the remaining stock of the fringe increases by one unit, which is to be considered as a cost for the cartel. The final term is a fixed cost factor: if the cartel does not produce at all, the fringe supplies  $\bar{p} - P^1$  and hence the stock of the fringe decreases by that amount.

One might not like outcomes with discontinuous price trajectories, because they can be deemed to open arbitrage opportunities in reality. However, if one wants to avoid this phenomenon the forces behind the absence of arbitrage should be modelled explicitly. For the present model price discontinuities are not excluded and can be beneficial for the cartel.

## II. CONCLUSION

It has been shown that the derivation of the open-loop van Stackelberg equilibrium in the cartel versus fringe model of the oil market by Newbery and Ulph has not been entirely correct. In several cases the true price trajectories will display one or two discontinuities. The main conclusion that the open-loop von Stackelberg equilibrium can be dynamically inconsistent is not affected and its consequences regarding the appropriateness of this equilibrium concept are not under dispute. However, our claim is that in deriving the equilibrium one should not only rely on intuition and let formal mathematical analysis do its work in checking for the merits of intuition.

*Free University Amsterdam*

*Eindhoven University of Technology*

*Tilburg University*

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## REFERENCES

- Groot, F., Withagen, C. and de Zeeuw, A. (1990). 'The binding-contracts Stackelberg equilibrium in the cartel-versus-fringe model reconsidered.' Center Discussion Paper 8924, Tilburg University.
- Neustadt, L. W. (1976). *Optimization. A Theory of Necessary Conditions*. New Jersey: Princeton University Press.
- Newbery, D. (1981). 'Oil prices, cartels, and the problem of dynamic inconsistency.' *ECONOMIC JOURNAL*, vol. 91, pp. 617-46.
- Seierstadt, A. and Sydsaeter, K. (1987). *Optimal Control Theory with Economic Applications*. Amsterdam: North-Holland.
- Ulph, A. (1982). 'Modeling partially cartelized markets for exhaustible resources.' In *Economic Theory of Natural Resources* (ed. W. Eichhorn *et al.*). Würzburg: Physica Verlag, pp. 269-91.
- Ulph, A. and Folie, G. (1980). 'Exhaustible resources and cartels: an intertemporal Nash-Cournot model.' *Canadian Journal of Economics*, vol. 13, pp. 645-58.

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- No. 1 G. Marini and F. van der Ploeg, Monetary and fiscal policy in an optimising model with capital accumulation and finite lives, *The Economic Journal*, vol. 98, no. 392, 1988, pp. 772 - 786.
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- No. 12 F. van der Ploeg, Towards monetary integration in Europe, in P. De Grauwe et al., *De Europese Monetaire Integratie: vier visies*, Wetenschappelijke Raad voor het Regeringsbeleid V 66, 's-Gravenhage: SDU uitgeverij, 1989, pp. 81 - 106.

- No. 13 R.J.M. Alessie and A. Kapteyn, Consumption, savings and demography, in A. Wenig, K.F. Zimmermann (eds.), *Demographic Change and Economic Development*, Berlin/Heidelberg: Springer-Verlag, 1989, pp. 272 - 305.
- No. 14 A. Hoque, J.R. Magnus and B. Pesaran, The exact multi-period mean-square forecast error for the first-order autoregressive model, *Journal of Econometrics*, vol. 39, no. 3, 1988, pp. 327 - 346.
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- No. 16 A. Holly and J.R. Magnus, A note on instrumental variables and maximum likelihood estimation procedures, *Annales d'Économie et de Statistique*, no. 10, April-June, 1988, pp. 121 - 138.
- No. 17 P. ten Hacken, A. Kapteyn and I. Woittiez, Unemployment benefits and the labor market, a micro/macro approach, in B.A. Gustafsson and N. Anders Klevmarcken (eds.), *The Political Economy of Social Security*, Contributions to Economic Analysis 179, Amsterdam: Elsevier Science Publishers B.V. (North-Holland), 1989, pp. 143 - 164.
- No. 18 T. Wansbeek and A. Kapteyn, Estimation of the error-components model with incomplete panels, *Journal of Econometrics*, vol. 41, no. 3, 1989, pp. 341 - 361.
- No. 19 A. Kapteyn, P. Kooreman and R. Willemse, Some methodological issues in the implementation of subjective poverty definitions, *The Journal of Human Resources*, vol. 23, no. 2, 1988, pp. 222 - 242.
- No. 20 Th. van de Klundert and F. van der Ploeg, Fiscal policy and finite lives in interdependent economies with real and nominal wage rigidity, *Oxford Economic Papers*, vol. 41, no. 3, 1989, pp. 459 - 489.
- No. 21 J.R. Magnus and B. Pesaran, The exact multi-period mean-square forecast error for the first-order autoregressive model with an intercept, *Journal of Econometrics*, vol. 42, no. 2, 1989, pp. 157 - 179.
- No. 22 F. van der Ploeg, Two essays on political economy: (i) The political economy of overvaluation, *The Economic Journal*, vol. 99, no. 397, 1989, pp. 850 - 855; (ii) Election outcomes and the stockmarket, *European Journal of Political Economy*, vol. 5, no. 1, 1989, pp. 21 - 30.
- No. 23 J.R. Magnus and A.D. Woodland, On the maximum likelihood estimation of multivariate regression models containing serially correlated error components, *International Economic Review*, vol. 29, no. 4, 1988, pp. 707 - 725.
- No. 24 A.J.J. Talman and Y. Yamamoto, A simplicial algorithm for stationary point problems on polytopes, *Mathematics of Operations Research*, vol. 14, no. 3, 1989, pp. 383 - 399.
- No. 25 E. van Damme, Stable equilibria and forward induction, *Journal of Economic Theory*, vol. 48, no. 2, 1989, pp. 476 - 496.

- No. 26 A.P. Barten and L.J. Bettendorf, Price formation of fish: An application of an inverse demand system, *European Economic Review*, vol. 33, no. 8, 1989, pp. 1509 - 1525.
- No. 27 G. Noldeke and E. van Damme, Signalling in a dynamic labour market, *Review of Economic Studies*, vol. 57 (1), no. 189, 1990, pp. 1 - 23.
- No. 28 P. Kop Jansen and Th. ten Raa, The choice of model in the construction of input-output coefficients matrices, *International Economic Review*, vol. 31, no. 1, 1990, pp. 213 - 227.
- No. 29 F. van der Ploeg and A.J. de Zeeuw, Perfect equilibrium in a model of competitive arms accumulation, *International Economic Review*, vol. 31, no. 1, 1990, pp. 131 - 146.
- No. 30 J.R. Magnus and A.D. Woodland, Separability and aggregation, *Economica*, vol. 57, no. 226, 1990, pp. 239 - 247.
- No. 31 F. van der Ploeg, International interdependence and policy coordination in economies with real and nominal wage rigidity, *Greek Economic Review*, vol. 10, no. 1, June 1988, pp. 1 - 48.
- No. 32 E. van Damme, Signaling and forward induction in a market entry context, *Operations Research Proceedings 1989*, Berlin-Heidelberg: Springer-Verlag, 1990, pp. 45 - 59.
- No. 33 A.P. Barten, Toward a levels version of the Rotterdam and related demand systems, *Contributions to Operations Research and Economics*, Cambridge: MIT Press, 1989, pp. 441 - 465.
- No. 34 F. van der Ploeg, International coordination of monetary policies under alternative exchange-rate regimes, in F. van der Ploeg (ed.), *Advanced Lectures in Quantitative Economics*, London-Orlando: Academic Press Ltd., 1990, pp. 91 - 121.
- No. 35 Th. van de Klundert, On socioeconomic causes of 'wait unemployment', *European Economic Review*, vol. 34, no. 5, 1990, pp. 1011 - 1022.
- No. 36 R.J.M. Alessie, A. Kapteyn, J.B. van Lochem and T.J. Wansbeek, Individual effects in utility consistent models of demand, in J. Hartog, G. Ridder and J. Theeuwes (eds.), *Panel Data and Labor Market Studies*, Amsterdam: Elsevier Science Publishers B.V. (North-Holland), 1990, pp. 253 - 278.
- No. 37 F. van der Ploeg, Capital accumulation, inflation and long-run conflict in international objectives, *Oxford Economic Papers*, vol. 42, no. 3, 1990, pp. 501 - 525.
- No. 38 Th. Nijman and F. Palm, Parameter identification in ARMA Processes in the presence of regular but incomplete sampling, *Journal of Time Series Analysis*, vol. 11, no. 3, 1990, pp. 239 - 248.
- No. 39 Th. van de Klundert, Wage differentials and employment in a two-sector model with a dual labour market, *Metroeconomica*, vol. 40, no. 3, 1989, pp. 235 - 256.

- No. 40 Th. Nijman and M.F.J. Steel, Exclusion restrictions in instrumental variables equations, *Econometric Reviews*, vol. 9, no. 1, 1990, pp. 37 - 55.
- No. 41 A. van Soest, I. Woittiez and A. Kapteyn, Labor supply, income taxes, and hours restrictions in the Netherlands, *Journal of Human Resources*, vol. 25, no. 3, 1990, pp. 517 - 558.
- No. 42 Th.C.M.J. van de Klundert and A.B.T.M. van Schaik, Unemployment persistence and loss of productive capacity: a Keynesian approach, *Journal of Macro- economics*, vol. 12, no. 3, 1990, pp. 363 - 380.
- No. 43 Th. Nijman and M. Verbeek, Estimation of time-dependent parameters in linear models using cross-sections, panels, or both, *Journal of Econometrics*, vol. 46, no. 3, 1990, pp. 333 - 346.
- No. 44 E. van Damme, R. Selten and E. Winter, Alternating bid bargaining with a smallest money unit, *Games and Economic Behavior*, vol. 2, no. 2, 1990, pp. 188 - 201.
- No. 45 C. Dang, The  $D_1$ -triangulation of  $\mathbb{R}^n$  for simplicial algorithms for computing solutions of nonlinear equations, *Mathematics of Operations Research*, vol. 16, no. 1, 1991, pp. 148 - 161.
- No. 46 Th. Nijman and F. Palm, Predictive accuracy gain from disaggregate sampling in ARIMA models, *Journal of Business & Economic Statistics*, vol. 8, no. 4, 1990, pp. 405 - 415.
- No. 47 J.R. Magnus, On certain moments relating to ratios of quadratic forms in normal variables: further results, *Sankhya: The Indian Journal of Statistics*, vol. 52, series B, part. 1, 1990, pp. 1 - 13.
- No. 48 M.F.J. Steel, A Bayesian analysis of simultaneous equation models by combining recursive analytical and numerical approaches, *Journal of Econometrics*, vol. 48, no. 1/2, 1991, pp. 83 - 117.
- No. 49 F. van der Ploeg and C. Withagen, Pollution control and the ramsey problem, *Environmental and Resource Economics*, vol. 1, no. 2, 1991, pp. 215 - 236.
- No. 50 F. van der Ploeg, Money and capital in interdependent economies with overlapping generations, *Economica*, vol. 58, no. 230, 1991, pp. 233 - 256.
- No. 51 A. Kapteyn and A. de Zeeuw, Changing incentives for economic research in the Netherlands, *European Economic Review*, vol. 35, no. 2/3, 1991, pp. 603 - 611.
- No. 52 C.G. de Vries, On the relation between GARCH and stable processes, *Journal of Econometrics*, vol. 48, no. 3, 1991, pp. 313 - 324.
- No. 53 R. Alessie and A. Kapteyn, Habit formation, interdependent preferences and demographic effects in the almost ideal demand system, *The Economic Journal*, vol. 101, no. 406, 1991, pp. 404 - 419.
- No. 54 W. van Groenendaal and A. de Zeeuw, Control, coordination and conflict on international commodity markets, *Economic Modelling*, vol. 8, no. 1, 1991, pp. 90 - 101.

- No. 55 F. van der Ploeg and A.J. Markink, Dynamic policy in linear models with rational expectations of future events: A computer package, *Computer Science in Economics and Management*, vol. 4, no. 3, 1991, pp. 175 - 199.
- No. 56 H.A. Keuzenkamp and F. van der Ploeg, Savings, investment, government finance, and the current account: The Dutch experience, in G. Alogoskoufis, L. Papademos and R. Portes (eds.), *External Constraints on Macroeconomic Policy: The European Experience*, Cambridge: Cambridge University Press, 1991, pp. 219 - 263.
- No. 57 Th. Nijman, M. Verbeek and A. van Soest, The efficiency of rotating-panel designs in an analysis-of-variance model, *Journal of Econometrics*, vol. 49, no. 3, 1991, pp. 373 - 399.
- No. 58 M.F.J. Steel and J.-F. Richard, Bayesian multivariate exogeneity analysis - an application to a UK money demand equation, *Journal of Econometrics*, vol. 49, no. 1/2, 1991, pp. 239 - 274.
- No. 59 Th. Nijman and F. Palm, Generalized least squares estimation of linear models containing rational future expectations, *International Economic Review*, vol. 32, no. 2, 1991, pp. 383 - 389.
- No. 60 E. van Damme, Equilibrium selection in  $2 \times 2$  games, *Revista Espanola de Economia*, vol. 8, no. 1, 1991, pp. 37 - 52.
- No. 61 E. Bennett and E. van Damme, Demand commitment bargaining: the case of apex games, in R. Selten (ed.), *Game Equilibrium Models III - Strategic Bargaining*, Berlin: Springer-Verlag, 1991, pp. 118 - 140.
- No. 62 W. Güth and E. van Damme, Gorby games - a game theoretic analysis of disarmament campaigns and the defense efficiency - hypothesis -, in R. Avenhaus, H. Karkar and M. Rudnianski (eds.), *Defense Decision Making - Analytical Support and Crisis Management*, Berlin: Springer-Verlag, 1991, pp. 215 - 240.
- No. 63 A. Roell, Dual-capacity trading and the quality of the market, *Journal of Financial Intermediation*, vol. 1, no. 2, 1990, pp. 105 - 124.
- No. 64 Y. Dai, G. van der Laan, A.J.J. Talman and Y. Yamamoto, A simplicial algorithm for the nonlinear stationary point problem on an unbounded polyhedron, *Siam Journal of Optimization*, vol. 1, no. 2, 1991, pp. 151 - 165.
- No. 65 M. McAleer and C.R. McKenzie, Keynesian and new classical models of unemployment revisited, *The Economic Journal*, vol. 101, no. 406, 1991, pp. 359 - 381.
- No. 66 A.J.J. Talman, General equilibrium programming, *Nieuw Archief voor Wiskunde*, vol. 8, no. 3, 1990, pp. 387 - 397.
- No. 67 J.R. Magnus and B. Pesaran, The bias of forecasts from a first-order autoregression, *Econometric Theory*, vol. 7, no. 2, 1991, pp. 222 - 235.



- No. 68 F. van der Ploeg, Macroeconomic policy coordination issues during the various phases of economic and monetary integration in Europe, *European Economy - The Economics of EMU*, Commission of the European Communities, special edition no. 1, 1991, pp. 136 - 164.
- No. 69 H. Keuzenkamp, A precursor to Muth: Tinbergen's 1932 model of rational expectations, *The Economic Journal*, vol. 101, no. 408, 1991, pp. 1245 - 1253.
- No. 70 L. Zou, The target-incentive system vs. the price-incentive system under adverse selection and the ratchet effect, *Journal of Public Economics*, vol. 46, no. 1, 1991, pp. 51 - 89.
- No. 71 E. Bomhoff, Between price reform and privatization: Eastern Europe in transition, *Finanzmarkt und Portfolio Management*, vol. 5, no. 3, 1991, pp. 241 - 251.
- No. 72 E. Bomhoff, Stability of velocity in the major industrial countries: a Kalman filter approach, *International Monetary Fund Staff Papers*, vol. 38, no. 3, 1991, pp. 626 - 642.
- No. 73 E. Bomhoff, Currency convertibility: when and how? A contribution to the Bulgarian debate, *Kredit und Kapital*, vol. 24, no. 3, 1991, pp. 412 - 431.
- No. 74 H. Keuzenkamp and F. van der Ploeg, Perceived constraints for Dutch unemployment policy, in C. de Neubourg (ed.), *The Art of Full Employment - Unemployment Policy in Open Economies*, Contributions to Economic Analysis 203, Amsterdam: Elsevier Science Publishers B.V. (North-Holland), 1991, pp. 7 - 37.
- No. 75 H. Peters and E. van Damme, Characterizing the Nash and Raiffa bargaining solutions by disagreement point axioms, *Mathematics of Operations Research*, vol. 16, no. 3, 1991, pp. 447 - 461.
- No. 76 P.J. Deschamps, On the estimated variances of regression coefficients in misspecified error components models, *Econometric Theory*, vol. 7, no. 3, 1991, pp. 369 - 384.
- No. 77 A. de Zeeuw, Note on 'Nash and Stackelberg solutions in a differential game model of capitalism', *Journal of Economic Dynamics and Control*, vol. 16, no. 1, 1992, pp. 139 - 145.
- No. 78 J.R. Magnus, On the fundamental bordered matrix of linear estimation, in F. van der Ploeg (ed.), *Advanced Lectures in Quantitative Economics*, London-Orlando: Academic Press Ltd., 1990, pp. 583 - 604.
- No. 79 F. van der Ploeg and A. de Zeeuw, A differential game of international pollution control, *Systems and Control Letters*, vol. 17, no. 6, 1991, pp. 409 - 414.
- No. 80 Th. Nijman and M. Verbeek, The optimal choice of controls and pre-experimental observations, *Journal of Econometrics*, vol. 51, no. 1/2, 1992, pp. 183 - 189.
- No. 81 M. Verbeek and Th. Nijman, Can cohort data be treated as genuine panel data?, *Empirical Economics*, vol. 17, no. 1, 1992, pp. 9 - 23.

- No. 82 E. van Damme and W. Güth, Equilibrium selection in the Spence signaling game, in R. Selten (ed.), *Game Equilibrium Models II - Methods, Morals, and Markets*, Berlin: Springer-Verlag, 1991, pp. 263 - 288.
- No. 83 R.P. Gilles and P.H.M. Ruys, Characterization of economic agents in arbitrary communication structures, *Nieuw Archief voor Wiskunde*, vol. 8, no. 3, 1990, pp. 325 - 345.
- No. 84 A. de Zeeuw and F. van der Ploeg, Difference games and policy evaluation: a conceptual framework, *Oxford Economic Papers*, vol. 43, no. 4, 1991, pp. 612 - 636.
- No. 85 E. van Damme, Fair division under asymmetric information, in R. Selten (ed.), *Rational Interaction - Essays in Honor of John C. Harsanyi*, Berlin/Heidelberg: Springer-Verlag, 1992, pp. 121 - 144.
- No. 86 F. de Jong, A. Kernna and T. Kloek, A contribution to event study methodology with an application to the Dutch stock market, *Journal of Banking and Finance*, vol. 16, no. 1, 1992, pp. 11 - 36.
- No. 87 A.P. Barten, The estimation of mixed demand systems, in R. Bewley and T. Van Hoa (eds.), *Contributions to Consumer Demand and Econometrics, Essays in Honour of Henri Theil*, Basingstoke: The Macmillan Press Ltd., 1992, pp. 31 - 57.
- No. 88 T. Wansbeek and A. Kapteyn, Simple estimators for dynamic panel data models with errors in variables, in R. Bewley and T. Van Hoa (eds.), *Contributions to Consumer Demand and Econometrics, Essays in Honour of Henri Theil*, Basingstoke: The Macmillan Press Ltd., 1992, pp. 238 - 251.
- No. 89 S. Chib, J. Osiewalski and M. Steel, Posterior inference on the degrees of freedom parameter in multivariate-*t* regression models, *Economics Letters*, vol. 37, no. 4, 1991, pp. 391 - 397.
- No. 90 H. Peters and P. Wakker, Independence of irrelevant alternatives and revealed group preferences, *Econometrica*, vol. 59, no. 6, 1991, pp. 1787 - 1801.
- No. 91 G. Alogoskoufis and F. van der Ploeg, On budgetary policies, growth, and external deficits in an interdependent world, *Journal of the Japanese and International Economies*, vol. 5, no. 4, 1991, pp. 305 - 324.
- No. 92 R.P. Gilles, G. Owen and R. van den Brink, Games with permission structures: The conjunctive approach, *International Journal of Game Theory*, vol. 20, no. 3, 1992, pp. 277 - 293.
- No. 93 J.A.M. Potters, I.J. Curiel and S.H. Tijs, Traveling salesman games, *Mathematical Programming*, vol. 53, no. 2, 1992, pp. 199 - 211.
- No. 94 A.P. Jurg, M.J.M. Jansen, J.A.M. Potters and S.H. Tijs, A symmetrization for finite two-person games, *Zeitschrift für Operations Research - Methods and Models of Operations Research*, vol. 36, no. 2, 1992, pp. 111 - 123.

- No. 95 A. van den Nouweland, P. Borm and S. Tijs, Allocation rules for hypergraph communication situations, *International Journal of Game Theory*, vol. 20, no. 3, 1992, pp. 255 - 268.
- No. 96 E.J. Bomhoff, Monetary reform in Eastern Europe, *European Economic Review*, vol. 36, no. 2/3, 1992, pp. 454 - 458.
- No. 97 F. van der Ploeg and A. de Zeeuw, International aspects of pollution control, *Environmental and Resource Economics*, vol. 2, no. 2, 1992, pp. 117 - 139.
- No. 98 P.E.M. Borm and S.H. Tijs, Strategic claim games corresponding to an NTU-game, *Games and Economic Behavior*, vol. 4, no. 1, 1992, pp. 58 - 71.
- No. 99 A. van Soest and P. Kooreman, Coherency of the indirect translog demand system with binding nonnegativity constraints, *Journal of Econometrics*, vol. 44, no. 3, 1990, pp. 391 - 400.
- No. 100 Th. ten Raa and E.N. Wolff, Secondary products and the measurement of productivity growth, *Regional Science and Urban Economics*, vol. 21, no. 4, 1991, pp. 581 - 615.
- No. 101 P. Kooreman and A. Kapteyn, On the empirical implementation of some game theoretic models of household labor supply, *The Journal of Human Resources*, vol. 25, no. 4, 1990, pp. 584 - 598.
- No. 102 H. Bester, Bertrand equilibrium in a differentiated duopoly, *International Economic Review*, vol. 33, no. 2, 1992, pp. 433 - 448.
- No. 103 J.A.M. Potters and S.H. Tijs, The nucleolus of a matrix game and other nucleoli, *Mathematics of Operations Research*, vol. 17, no. 1, 1992, pp. 164 - 174.
- No. 104 A. Kapteyn, P. Kooreman and A. van Soest, Quantity rationing and concavity in a flexible household labor supply model, *Review of Economics and Statistics*, vol. 72, no. 1, 1990, pp. 55 - 62.
- No. 105 A. Kapteyn and P. Kooreman, Household labor supply: What kind of data can tell us how many decision makers there are?, *European Economic Review*, vol. 36, no. 2/3, 1992, pp. 365 - 371.
- No. 106 Th. van de Klundert and S. Smulders, Reconstructing growth theory: A survey, *De Economist*, vol. 140, no. 2, 1992, pp. 177 - 203.
- No. 107 N. Rankin, Imperfect competition, expectations and the multiple effects of monetary growth, *The Economic Journal*, vol. 102, no. 413, 1992, pp. 743 - 753.
- No. 108 J. Greenberg, On the sensitivity of von Neumann and Morgenstern abstract stable sets: The stable and the individual stable bargaining set, *International Journal of Game Theory*, vol. 21, no. 1, 1992, pp. 41 - 55.
- No. 109 S. van Wijnbergen, Trade reform, policy uncertainty, and the current account: A non-expected-utility approach, *American Economic Review*, vol. 82, no. 3, 1992, pp. 626 - 633.

- No. 110 M. Verbeek and Th. Nijman, Testing for selectivity bias in panel data models, *International Economic Review*, vol. 33, no. 3, 1992, pp. 681 - 703.
- No. 111 Th. Nijman and M. Verbeek, Nonresponse in panel data: The impact on estimates of a life cycle consumption function, *Journal of Applied Econometrics*, vol. 7, no. 3, 1992, pp. 243 - 257.
- No. 112 I. Bomze and E. van Damme, A dynamical characterization of evolutionarily stable states, *Annals of Operations Research*, vol. 37, 1992, pp. 229 - 244.
- No. 113 P.J. Deschamps, Expectations and intertemporal separability in an empirical model of consumption and investment under uncertainty, *Empirical Economics*, vol. 17, no. 3, 1992, pp. 419 - 450.
- No. 114 K. Kamiya and D. Talman, Simplicial algorithm for computing a core element in a balanced game, *Journal of the Operations Research*, vol. 34, no. 2, 1991, pp. 222 - 228.
- No. 115 G.W. Imbens, An efficient method of moments estimator for discrete choice models with choice-based sampling, *Econometrica*, vol. 60, no. 5, 1992, pp. 1187 - 1214.
- No. 116 P. Borm, On perfectness concepts for bimatrix games, *OR Spektrum*, vol. 14, no. 1, 1992, pp. 33 - 42.
- No. 117 A.P. Jurg, I. Garcia Jurado and P.E.M. Borm, On modifications of the concepts of perfect and proper equilibria, *OR Spektrum*, vol. 14, no. 2, 1992, pp. 85 - 90.
- No. 118 P. Borm, H. Keiding, R.P. McLean, S. Oortwijn and S. Tijs, The compromise value for NTU-games, *International Journal of Game Theory*, vol. 21, no. 2, 1992, pp. 175 - 189.
- No. 119 M. Maschler, J.A.M. Potters and S.H. Tijs, The general nucleolus and the reduced game property, *International Journal of Game Theory*, vol. 21, no. 1, 1992, pp. 85 - 106.
- No. 120 K. Wärneryd, Communication, correlation and symmetry in bargaining, *Economics Letters*, vol. 39, no. 3, 1992, pp. 295 - 300.
- No. 121 M.R. Baye, D. Kovenock and C.G. de Vries, It takes two to tango: equilibria in a model of sales, *Games and Economic Behavior*, vol. 4, no. 4, 1992, pp. 493 - 510.
- No. 122 M. Verbeek, Pseudo panel data, in L. Mátyás and P. Sevestre (eds.), *The Econometrics of Panel Data*, Dordrecht: Kluwer Academic Publishers, 1992, pp. 303 - 315.
- No. 123 S. van Wijnbergen, Intertemporal speculation, shortages and the political economy of price reform, *The Economic Journal*, vol. 102, no. 415, 1992, pp. 1395 - 1406.
- No. 124 M. Verbeek and Th. Nijman, Incomplete panels and selection bias, in L. Mátyás and P. Sevestre (eds.), *The Econometrics of Panel Data*, Dordrecht: Kluwer Academic Publishers, 1992, pp. 262 - 302.

- No. 125 J.J. Sijben, Monetary policy in a game-theoretic framework, *Jahrbücher für Nationalökonomie und Statistik*, vol. 210, no. 3/4, 1992, pp. 233 - 253.
- No. 126 H.A.A. Verbon and M.J.M. Verhoeven, Decision making on pension schemes under rational expectations, *Journal of Economics*, vol. 56, no. 1, 1992, pp. 71 - 97.
- No. 127 L. Zou, Ownership structure and efficiency: An incentive mechanism approach, *Journal of Comparative Economics*, vol. 16, no. 3, 1993, pp. 399 - 431.
- No. 128 C. Fershtman and A. de Zeeuw, Capital accumulation and entry deterrence: A clarifying note, in G. Feichtinger (ed.), *Dynamic Economic Models and Optimal Control*, Amsterdam: Elsevier Science Publishers B.V. (North-Holland), 1992, pp. 281 - 296.
- No. 129 L. Bovenberg and C. Petersen, Public debt and pension policy, *Fiscal Studies*, vol. 13, no. 3, 1992, pp. 1 - 14.
- No. 130 R. Gradus and A. de Zeeuw, An employment game between government and firms, *Optimal Control Applications & Methods*, vol. 13, no. 1, 1992, pp. 55 - 71.
- No. 131 Th. Nijman and R. Beetsma, Empirical tests of a simple pricing model for sugar futures, *Annales d'Économie et de Statistique*, no. 24, 1991, pp. 121 - 131.
- No. 132 F. Groot, C. Withagen and A. de Zeeuw, Note on the open-loop Von Stackelberg equilibrium in the Cartel versus Fringe model, *The Economic Journal*, vol. 102, no. 415, 1992, pp. 1478 - 1484.

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