A decision rule for the (des)investments in the dairy cow stock
Roemen, J.H.J.

Publication date:
1991

Link to publication

Citation for published version (APA):
A DECISION RULE FOR THE (DES)INVESTMENTS IN THE DAIRY COW STOCK

J.H.J. Roemen

FEW 495
A DECISION RULE FOR THE (DES)INVESTMENTS IN THE DAIRY COW STOCK

J.H.J. Roemen

Abstract

In this paper we present (a simplified version of) an alpha-numerically specified model for the development of the national milk supply in the long run. From this model we derive reaction equations for the optimal level of the (des)investments in the dairy cow stock. These relations can be used as a starting point for e.g. the estimation of the long run elasticity of the milk supply with respect to the milk price.

1. Introduction

The national milk supply is equal to the product of the average milk production per cow and the size of the national dairy cow stock. In normal circumstances the size of this stock is approximately constant in the short run, that is, within one year, hence the main possibility in the short run for modifying the national supply in response to a changing milk price is the yield per cow. In the long run, however, the level of supply can also be changed by altering the size of the stock. This can be effected by putting in calf (inseminating) more (less) heifers this year than will be needed as replacements in the following year, by the level of culling or finally by a combination of these possibilities.

In this paper we present a simplified model of the determinants of the milk supply development in the long run. Because the individual farmer decides upon (changes in) this supply, we consider the underlying decision process at the farm as an obvious point of departure. For this farm we formulate a dynamic, alpha-numerically specified model of milk supply. From this model we derive decision rules for the optimal level of the
(des)investments in the dairy cow stock. The resulting reaction equations specify these levels as a function of, among other things, present and expected prices. So these relations provide a starting point for e.g. the estimation of the long run elasticity of the milk supply with respect to the milk price, using farm data. If we assume that the same type of model as the one considered here holds for all firms in the sector, the requirements for consistent estimation are satisfied, and estimation using sector data is also allowed.

2. The problem

To get an idea of the considerations which determine the size and age composition of the dairy cow stock, and so the levels of in- and outflow, we consider an individual dairy farm that is primarily directed towards milk production by cows from own breeding. In so far as the farmer judges a change of the stock size desirable, he chooses in every period from among the heifer calves, that are born in that period out of this herd, a number for the purpose of breeding. All other heifer calves and all the bull calves he sells for fattening to other specialized farms. As soon as the selected calves have reached the age when they can reproduce, they are put in calf, if they still meet the selection requirements, and sold for slaughter if they do not. After completing the gestation period of nine months as heifer in calf, these animals enter the farm's dairy herd as cow. After four to five lactation periods (and calves) they are finally sold for slaughter, because they are no longer sufficiently productive. For reasons of consistent aggregation the farmer is neither allowed to buy breeding-cattle from other dairy farms nor to sell it to other dairy farms.

Now, every year again, the farmer faces the same problem. How many of the heifer calves born should be retained at the farm for breeding, how many heifers should be sold for slaughter or put in calf and finally how many cows should be culled. As soon as he has reached this decision, the development of the live stock in that period is known, given the opening stock and ignoring loss by death. We assume that the dairy farmer must take such decisions for T consecutive years. At the end of year T he sells
his livestock to a new owner. Because revenues and expenses are distributed over the life time of the animals, this decision problem is really an investment problem.

In deciding upon these questions it holds that the possibilities in a particular period are partly dependent on decisions taken in the past, just as this period's decisions (co)determine the farm's future herd development. It also holds that the farmer in determining the size and age composition of the stock must take into account the capacities of labor, dead stock and funds he has at his disposal. His decisions must always fit within the framework given by these factors. In this paper however we will neither pay attention to the coherence and interaction between these factors and the live stock nor to the possibility and consequences of extending the capacities of these factors. For simplicity's sake we confine ourselves to the live stock. Extensions are dealt with in [4].

One can, on good grounds, hold the view that a farmer, in choosing from a set of alternatives, is satisfied, as soon as he reaches his aspiration level. Here, however, we will not proceed from a satisfying, but from a maximising concept. The objective used here is maximization of the value of (discounted) cash-flows, generated by the farmer's decisions. This criterion, though one-sided, without doubt forms an important element in comparing alternatives, directly related as it is to the consumption possibilities of these production/consumption households. Of course, in such an approach leisure has no value.

3. The model

We assume that the lactation and dry period together make up a year, so every cow in calf gives birth to one calf a year, with equal probability a heifer or a bull calf. During the year following on that in which a heifer calf is born, it enters the heifer (or yearling) category. Heifers can be put in calf (inseminated) or sold for slaughter, either in the year of entering the heifer category or later on. We suppose that between the moment of a heifer's insemination and its calving lies a period of a year, too.

Let $\nu_t, \rho_t, v_t, c_t, t = 0, 1, \ldots, T$ denote the number of respectively heifer calves, heifers, heifers in calf and lactating cows at the farm at
time \( t \), \( v v k_t \), \( v p_t \), \( v c_t \) the number of heifer calves, heifers and cows, sold for slaughter in year \( t \), and \( d_t \) the number of heifers put in calf in year \( t \). The development of the farm's herd can now be represented by the following equations:

\[
\begin{align*}
v k_t &= \frac{1}{2} (v t_{t-1} + c t_{t-1}) - v v k_t \\
p_t &= v k_{t-1} + p t_{t-1} - v p_t - d_t \\
v_t &= d_t \\
c_t &= v t_{t-1} + c t_{t-1} - v c_t
\end{align*}
\]

In matrix notation this reads

\[
Y_t = C_1 Y_{t-1} + C_2 X_t,
\]

where

\[
Y_t' = [v k_t, p_t, v_t, c_t], X_t' = [v v k_t, v p_t, d_t, v c_t].
\]

\[
C_1 = \begin{bmatrix} 0 & 0 & 1 & 1 \\ 1 & 1 & 0 & 0 \end{bmatrix}, \quad C_2 = \begin{bmatrix} -1 & 0 & 0 & 0 \\ 0 & -1 & -1 & 0 \end{bmatrix}
\]

As remarked above transactions in breeding-cattle between dairy farms will be left out of consideration, because such transactions have no influence on the investment level of the sector as a whole. In view of that the vector of decision variables, \( X_t \), is required to be non-negative. Also, no more heifer calves, heifers or cows can be sold for slaughter (or inseminated) than available. Supposing that \( X_t \) never reaches its minimum or maximum, we can leave out of consideration the related restrictions. As a consequence, the decision problem to be formulated at the end of this section is sizably simplified.

Also, the opening stock being positive,
the vector $Y_t$ will always be positive.

In deciding upon the size and age structure of the livestock the farmer is, as stated, guided by the objective of maximizing the value of discounted cash flows evoked by his decisions.

Revenues accrue to the farm from the delivery of milk to the dairy industry, the sale of heifer and bull calves, and the sale of heifers and culled cows for slaughter.

The level of milk production by the dairy herd depends on many factors. Important in the long term analysis here are breed, age composition and genetic potential of the average cow. Keeping breed constant we suppose that the revenues from milk in year $t$ are

$$p_m t(1+g)^t \{a_1 c_{t-1} + a_3 v_{t-1} - a_5 v_{c_t}\}, \quad (3.4)$$

where $p_m t$ denotes the price of milk in year $t$, $g$ the genetic improvement in percent a year and $a_1$, $a_3$, $a_5$ the milk yield per dairy cattle category (for culled cows $a_1$-$a_5$).

Revenues from the sale of cattle amount to

$$p_k t \left\{ \frac{1}{2} (c_{t-1} + v_{t-1}) + v v_{k_t} \right\} + pp_t v_p t + pc_t v_{c_t}, \quad (3.5)$$

where $p_k t$, $pp_t$ and $pc_t$ denote the price of a calf, a heifer and a culled cow respectively. We suppose that these prices are independent of the numbers sold.

In a more complete representation the revenues side also comprises cash receipts from borrowing, but, as remarked before, the aspect of financing the investment/production activities by own or borrowed funds will not be considered here.

Expenditures are done for the acquisition of dead stock, the payment of interest and redemption of debt and for buying concentrates, fertiliser, fuel etc. In this paper, however, we confine ourselves to those expenses which can without allocation be attributed to the livestock, e.g. concentrates. We will specify these expenses as a quadratic function of the distinct cattle categories. Having a linear revenues function we
achieve in such a manner that there exists an optimal size of the live stock. The parameters of this expenditures function reflect the prices of the inputs, such as fodder bought, and the state of technology. We assume, that all of these coefficients change conform inflation during the planning period.

Within the expenses evoked by the live stock we discern on the one hand expenditures determined by the size of a cattle category and on the other hand expenditures determined by the age composition of a category. Leaving inflation a moment aside the size dependent expenditures comprise the following four components, one for each cattle category.

\[
\begin{align*}
\frac{1}{2} b_1 v_{kt}^2 &= \frac{1}{2} b_1 (\frac{1}{2} v_{t-1} + \frac{1}{2} c_{t-1} - v_{kt})^2 \\
\frac{1}{2} b_2 p_{kt}^2 &= \frac{1}{2} b_2 (p_{t-1} + v_{k_{t-1}} - v_{p_{t}} - d_{t})^2 \\
\frac{1}{2} b_3 v_{t}^2 &= \frac{1}{2} b_3 d_{t}^2 \\
\frac{1}{2} b_4 c_{t}^2 &= \frac{1}{2} b_4 (v_{t-1} + c_{t-1} - v_{c_{t}})^2
\end{align*}
\]

(3.6)

On top of these come the age dependent expenditures which arise when the animals within a category on average become older or younger.

\[
\begin{align*}
\frac{1}{2} b_5 (p_{t-1} - v_{p_{t}} - d_{t})^2 \\
\frac{1}{2} b_6 (c_{t-1} - v_{c_{t}})^2
\end{align*}
\]

(3.7)

If \( p_{t-1} \) is equal to \( v_{p_{t}} + d_{t} \), the breeding expenses for heifers in that period amount to \( \frac{1}{2} b_2 v_{kt-1}^2 \). If, however \( v_{p_{t}} \) and \( d_{t} \) are both equal to 0, then these expenses total \( \frac{1}{2} b_2 (p_{t-1} + v_{k_{t-1}})^2 + \frac{1}{2} b_5 p_{t-1}^2 \).

The sum of the expenditures components (3.6) and (3.7) will be denoted by the symbol \( TE_t \).

The net returns to the farmer in guilders of constant purchasing power can now be summarized by the following expression:
where \( \hat{\pi}_j \) denotes the inflation percentage in year \( j \).

\[
P'_y, t = [0, 0, \frac{1}{2} p_{k_t} + pm_t(1+g)^{t}a_3, \frac{1}{2} p_{k_t} + pm_t(1+g)^{t}a_1]
\]

\[
P'_x, t = [p_{k_t}, p_{p_t}, 0, p_{c_t} - pm_t(1+g)^{t}a_5]
\]

and

\[
A_1 = \frac{\partial^2 \theta_{E_t}}{\partial Y_{t-1}^2}, A_2 = \frac{\partial^2 \theta_{E_t}}{\partial Y_{t-1} \partial X_{t}}, A_4 = \frac{\partial^2 \theta_{E_t}}{\partial X_{t}^2}
\]

For year \( T \), the sale of the stock comes on top of the revenues in that year.

Now that a specification of net returns is available, the decision problem the farmer faces in the first year within the planning horizon can be represented by the following model, compare also [1] and [3],

\[
\max F = \sum_{t=1}^{T} \beta^t \left\{ \prod_{j=1}^{t} (1+\hat{\pi}_j) \right\}^{-1} \left\{ 1_p^E Y_{t-1} + 1_p^E X_{t} \right\} + \beta^T \left\{ \prod_{j=1}^{T} (1+\hat{\pi}_j) \right\}^{-1} \left\{ 1_p^E Y_{T+1} + 1_p^E Y_{T} \right\}
\]

subject to

\[
Y_t = C_1 Y_{t-1} + C_2 X_t
\]

\[
Y_0 = \bar{Y}_0
\]

Here \( \beta \) denotes the discount factor the farmer uses and \( \hat{\pi}_j \) the inflation percentage that he in year 1 expects to be valid for year \( j \). The vectors \( 1_p^E Y_{t} \) and \( 1_p^E X_{t} \) specify his expectations in year 1 with respect to the returns from milk delivery and cattle sales in year \( t \).
Finally, the vector \( \mathbf{p}_{y,t} = [0, 0, \frac{1}{2} \mathbf{p}_{y,t}^E + \frac{1}{2} \mathbf{m}_{t}^E(1+g) \mathbf{t}_{a_3}, \frac{1}{2} \mathbf{p}_{y,t}^E + \frac{1}{2} \mathbf{m}_{t}^E(1+g) \mathbf{t}_{a_1}] \)

\( \mathbf{p}_{x,t} = [\mathbf{p}_{x,t}^E, \mathbf{p}_{x,t}, 0, \mathbf{p}_{x,t}^E - \mathbf{m}_{t}^E(1+g) \mathbf{t}_{a_5}] \)

denotes the prices the farmer expects to receive from selling his livestock to a new owner at the end of the planning horizon. The expected prices for the first year are, of course, equal to the actual prices in that year, i.e. \( \mathbf{p}_{y,1}^E = \mathbf{p}_{y,1} \) and \( \mathbf{p}_{x,1}^E = \mathbf{p}_{x,1} \).

\[ \text{4. The solution} \]

The decision problem (3.9) (and those for the following years which possess the same structure) can be solved in several ways, e.g. recursively. Now for some as yet unknown reason it holds, that

\[ (C_1 - C_2 A_4^{-1} A_2')^2 = 0 \]

and

\[ (C_1 - C_2 A_4^{-1} A_2')(A_1 - A_2 A_4^{-1} A_2') = 0 \]

Using these features we can obtain the optimal solution in a simple way. This solution is

\[ X_t = -A_2^{-1} A_2' Y_{t-1} + Q_{t-1} W_t, \quad t = 1, \ldots, T-2 \]

where

\[ Q_t = A_4 + \beta C_2' (A_1 - A_2 A_4^{-1} A_2') C_2, \]

\[ W_t = \left\{ \prod_{j=1}^{t} \left( 1 + i_j \right) \right\}^{-1} \left( p_{x,t} + \left( 1 + t_{t-1}^E \right)^{-1} \beta C_2' \left( t_{y,t+1}^E - A_2 A_4^{-1} P_{x,t+1}^E \right) + \left( t_{t-1}^E \right)^{-1} \beta C_2' \left( t_{y,t+2}^E - A_2 A_4^{-1} P_{x,t+2}^E \right) \right. \]

\[ + \left. \left( 1 + t_{t+1}^E \right) \left( 1 + t_{t+2}^E \right)^{-1} \beta^2 C_2' \left( t_{y,t+2}^E - A_2 A_4^{-1} P_{x,t+2}^E \right) \right\}^{-1} \]
For space considerations the slightly different expressions for T-1 and T are omitted. For the same reason we will not write down the whole solution in extenso. Instead we present the decision rules in which we are interested here: the investments, \( d_t \), and the desinvestments, \( v_{ct} \).

For the simple model considered here the optimal level of the inflow of heifers in calf in the dairy stock is given by the following expression, obtained by using a formula manipulation language,

\[
d_t = -\frac{b_4 + b_6}{n_3} pp_t + \frac{\beta(b_4 + b_6)}{(1 + i_t)^n_3} t^{pk_{t+1}} + \frac{\beta(1 + g)^{t+1}(b_4(a_3 - a_5) + b_6 a_3)}{(1 + i_t)^n_3} t^{pm_{t+1}} + \frac{\beta b_4}{(1 + i_t)^n_3} t^{pc_{t+1}} + \frac{\beta^2 b_6}{(1 + i_t)^n_3} t^{pk_{t+2}} + \frac{\beta^2(1 + g)^{t+2} b_6(a_1 - a_5)}{(1 + i_t)^n_3} t^{pm_{t+2}} + \frac{\beta^2 b_6}{(1 + i_t)^n_3} t^{pc_{t+2}}
\]

(4.6)

where \( n_3 = \prod_{j=1}^{t} (1 + i_j)(2b_4b_6 + b_4b_3 + b_6 b_3) \).

For the optimal culling level we find

\[
v_{ct} = \frac{b_4}{n_4} v_{t-1} + \frac{(1 + g)^t a_5}{\prod_{j=1}^{t} (1 + i_j)n_4} p_{mt} + \frac{1}{\prod_{j=1}^{t} (1 + i_j)n_4} p_{ct} + \frac{\beta}{\prod_{j=1}^{t} (1 + i_j)(1 + i_t)n_4} t^{pk_{t+1}} - \frac{\beta(1 + g)^{t+1}(a_1 - a_5)}{\prod_{j=1}^{t} (1 + i_j)(1 + i_t)n_4} t^{pm_{t+1}} - \frac{\beta}{\prod_{j=1}^{t} (1 + i_j)(1 + i_t)^2n_4} t^{pc_{t+1}}
\]

(4.7)

where \( n_4 = b_4 + b_6 \).
If \( c_{t-1} \) in (4.7) is brought from the right to the left hand side and \( c_{t-1} - v_t \) is substituted by \( c_t - v_{t-1} \), (4.7) becomes

\[
c_t = \frac{b_6}{n_4} v_{t-1} + \frac{(1+g)^{t-a_2}}{\prod (1+i_j)n_4} \frac{p_m}{t} - \frac{1}{\prod (1+i_j)n_4} p_c + \frac{\beta}{t} \frac{E}{\prod (1+i_j)(1+t_{t+1})n_4} + \frac{\beta(1+g)^{t+1}(a_1-a_2)}{t} \frac{E}{\prod (1+i_j)(1+t_{t+1})n_4} + \frac{\beta}{t} \frac{E}{\prod (1+i_j)(1+t_{t+1})n_4}
\]

(4.8)

The investments in year \( t \) are according to (4.6) determined by the (deflated) actual and expected prices. The desinvestments in year \( t \), (4.7), also depend on the size of the dairy herd at time \( t-1 \) and the inflow in period \( t-1 \). The weight of each factor depends on coefficients from the revenues and expenditures functions. Curious about (4.6) and (4.7) and the other equations in (4.3) is that its variables only refer to the current and the future two years. One would rather expect the prices of all future periods to play a role. It must be admitted that these rules are hardly interpretable in economic terms. Of course, on the basis of the derivation followed, it can not be misunderstood that the equality of marginal revenues and costs hides behind these expressions, but it is not clear how to state this in economic terms.

In (4.6) and (4.7) the factors are identified which determine the (optimal) level of the (des)investment in the dairy stock and also the specific influence of each of these variables. By means of these relations one can assess to what extent the stock size (and so cet.par. the level of the milk supply) reacts on changes in the price for milk.

The average size of the dairy cow stock in period \( t \) amounts to

\[
\bar{c}_t = \frac{c_{t-1} + c_t}{2}
\]

(4.9)
The insertion of (4.8) in (4.9) gives this average as a function of amongst others the prices and price expectations in that period. In view of the dependence of \( c_{t+1} \) on \( v_t \) these prices also influence \( c_{t+1} \) and \( c_{t+2} \). Under the assumption that the milk price expectations in (4.6) and (4.8) only depend on \( p_{mt} \), as far as it concerns milk prices, the effect of a change in the milk price in period \( t \) on the average size of the dairy cow stock is expressed by

\[
\frac{\partial c_t}{\partial p_{mt}} + \frac{\partial c_{t+1}}{\partial p_{mt}} + \frac{\partial v_t}{\partial v_t} \left( \frac{\partial v_t}{\partial p_{mt}} \right) + \frac{\partial v_t}{\partial p_{mt}} \left( \frac{\partial v_t}{\partial p_{mt}} \right) + \frac{\partial v_t}{\partial p_{mt}} \left( \frac{\partial v_t}{\partial p_{mt}} \right) = \]

\[(4.10)\]

or, shortly, by

\[
\frac{\partial c_t}{\partial p_{mt}} + \frac{\partial c_{t+1}}{\partial p_{mt}} \frac{\partial v_t}{\partial v_t}
\]

(4.11)

Under the assumption just mentioned the long run elasticity, \( \frac{\Delta c}{\Delta p_{mt}} \), can be determined by for instance the average of the elasticities in the several years.

\[
\frac{\Delta c}{\Delta p_{mt}} = \frac{1}{T} \sum_{t=1}^{T} \left( \frac{\partial c_t}{\partial p_{mt}} + \frac{\partial c_{t+1}}{\partial v_t} \frac{\partial v_t}{\partial p_{mt}} \right) \frac{p_{mt}}{c_t}
\]

(4.12)

The elements \( \frac{\partial c_t}{\partial p_{mt}} \), \( \frac{\partial c_{t+1}}{\partial p_{mt}} \), and \( \frac{\partial v_t}{\partial p_{mt}} \), can be obtained by means of the estimates for the corresponding regression coefficients. Should the milk price expectations in (4.6) and (4.8) also depend on other milk prices than the one of period \( t \), then (4.10) has to be adjusted accordingly.

The reaction equations (4.6) and (4.8) are derived at micro level, so the elasticity (4.12) can be estimated using data concerning individual farms. However, if we assume that the same type of model as the one derived holds for all firms in the sector, the conditions for consistent aggregation are satisfied and estimation of (4.12) using data with respect to the sector as a whole is also allowed [4].
5. Conclusion

We have shown above how from a model for the long term development of milk supply decision rules for the (des)investments in the dairy cow stock can be derived. Such rules supply a starting point for e.g. a statistical investigation into the long run reaction of the milk production to the milk price. More realistic rules result when dead stock and debt financing are incorporated.

Acknowledgement

The author wishes to thank A. Markink for programming support.

Literature


IN 1990 REEDS VERSCHENEN

419 Bertrand Melenberg, Rob Alessie
A method to construct moments in the multi-good life cycle consumption model

420 J. Kriens
On the differentiability of the set of efficient \((\mu, \sigma^2)\) combinations in the Markowitz portfolio selection method

421 Steffen Jørgensen, Peter M. Kort
Optimal dynamic investment policies under concave-convex adjustment costs

422 J.P.C. Blanc
Cyclic polling systems: limited service versus Bernoulli schedules

423 M.H.C. Paardekooper
Parallel normreducing transformations for the algebraic eigenvalue problem

424 Hans Gremmen
On the political (ir)relevance of classical customs union theory

425 Ed Nijssen
Marketingstrategie in Machtsperspectief

426 Jack P.C. Kleijnen
Regression Metamodels for Simulation with Common Random Numbers: Comparison of Techniques

427 Harry H. Tigelaar
The correlation structure of stationary bilinear processes

428 Drs. C.H. Veld en Drs. A.H.F. Verboven
De waardering van aandelenwarrants en langlopende call-opties

429 Theo van de Klundert en Anton B. van Schaik
Liquidity Constraints and the Keynesian Corridor

430 Gert Nieuwenhuis
Central limit theorems for sequences with \(m(n)\)-dependent main part

431 Hans J. Gremmen
Macro-Economic Implications of Profit Optimizing Investment Behaviour

432 J.M. Schumacher
System-Theoretic Trends in Econometrics

433 Peter M. Kort, Paul M.J.J. van Loon, Mikulás Luptacik
Optimal Dynamic Environmental Policies of a Profit Maximizing Firm

434 Raymond Gradus
Optimal Dynamic Profit Taxation: The Derivation of Feedback Stackelberg Equilibria
Jack P.C. Kleijnen  
Statistics and Deterministic Simulation Models: Why Not?

M.J.G. van Eijs, R.J.M. Heuts, J.P.C. Kleijnen  
Analysis and comparison of two strategies for multi-item inventory systems with joint replenishment costs

Jan A. Weststrate  
Waiting times in a two-queue model with exhaustive and Bernoulli service

Alfons Daems  
Typologie van non-profit organisaties

Drs. C.H. Veld en Drs. J. Grazell  
Motieven voor de uitgifte van converteerbare obligatieleningen en warrantobligatieleningen

Jack P.C. Kleijnen  
Sensitivity analysis of simulation experiments: regression analysis and statistical design

C.H. Veld en A.H.F. Verboven  
De waardering van conversierechten van Nederlandse converteerbare obligaties

Drs. C.H. Veld en Drs. P.J.W. Duffhues  
Verslaggevingsaspecten van aandelenwarrants

Jack P.C. Kleijnen and Ben Annink  
Vector computers, Monte Carlo simulation, and regression analysis: an introduction

Alfons Daems  
"Non-market failures": Imperfections in de budgetsector

J.P.C. Blanc  
The power-series algorithm applied to cyclic polling systems

L.W.G. Strijbosch and R.M.J. Heuts  
Modelling (s,Q) inventory systems: parametric versus non-parametric approximations for the lead time demand distribution

Jack P.C. Kleijnen  
Supercomputers for Monte Carlo simulation: cross-validation versus Rao's test in multivariate regression

Jack P.C. Kleijnen, Greet van Ham and Jan Rotmans  
Techniques for sensitivity analysis of simulation models: a case study of the CO₂ greenhouse effect

Harrie A.A. Verbon and Marijn J.M. Verhoeven  
Decision-making on pension schemes: expectation-formation under demographic change
Drs. W. Reijnders en Drs. P. Verstappen
Logistiek management marketinginstrument van de jaren negentig

Alfons J. Daems
Budgeting the non-profit organization
An agency theoretic approach

W.H. Haemers, D.G. Higman, S.A. Hobart
Strongly regular graphs induced by polarities of symmetric designs

M.J.G. van Eijs
Two notes on the joint replenishment problem under constant demand

B.B. van der Genugten
Iterated WLS using residuals for improved efficiency in the linear model with completely unknown heteroskedasticity

F.A. van der Duyn Schouten and S.G. Vanneste
Two Simple Control Policies for a Multicomponent Maintenance System

Geert J. Almekinders and Sylvester C.W. Eijffinger
Objectives and effectiveness of foreign exchange market intervention
A survey of the empirical literature

Saskia Oortwijn, Peter Borm, Hans Keiding and Stef Tijs
Extensions of the τ-value to NTU-games

Willem H. Haemers, Christopher Parker, Vera Pless and Vladimir D. Tonchev
A design and a code invariant under the simple group Co3

J.P.C. Blanc
Performance evaluation of polling systems by means of the power-series algorithm

Leo W.G. Strijbosch, Arno G.M. van Doorne, Willem J. Selen
A simplified MOLP algorithm: The MOLP-S procedure

Arie Kapteyn and Aart de Zeeuw
Changing incentives for economic research in The Netherlands

W. Spanjers
Equilibrium with co-ordination and exchange institutions: A comment

Sylvester Eijffinger and Adrian van Rixtel
The Japanese financial system and monetary policy: A descriptive review

Hans Kremers and Dolf Talman
A new algorithm for the linear complementarity problem allowing for an arbitrary starting point

René van den Brink, Robert P. Gilles
A social power index for hierarchically structured populations of economic agents
IN 1991 REEDS VERSCHENEN

466 Prof.Dr. Th.C.M.J. van de Klundert - Prof.Dr. A.B.T.M. van Schaik
Economische groei in Nederland in een internationaal perspectief

467 Dr. Sylvester C.W. Eijffinger
The convergence of monetary policy - Germany and France as an example

468 E. Nijssen
Strategisch gedrag, planning en prestatie. Een inductieve studie
binnen de computerbranche

469 Anne van den Nouweland, Peter Borm, Guillermo Owen and Stef Tijs
Cost allocation and communication

470 Drs. J. Grazell en Drs. C.H. Veld
Motieven voor de uitgifte van converteerbare obligatieleningen en
warrant-obligatieleningen: een agency-theoretische benadering

471 P.C. van Batenburg, J. Kriens, W.M. Lammerts van Bueren and
R.H. Veenstra
Audit Assurance Model and Bayesian Discovery Sampling

472 Marcel Kerkhofs
Identification and Estimation of Household Production Models

473 Robert P. Gilles, Guillermo Owen, René van den Brink
Games with Permission Structures: The Conjunctive Approach

474 Jack P.C. Kleijnen
Sensitivity Analysis of Simulation Experiments: Tutorial on Regression
Analysis and Statistical Design

475 An O(nlogn) algorithm for the two-machine flow shop problem with
controllable machine speeds
C.P.M. van Hoesel

476 Stephan G. Vanneste
A Markov Model for Opportunity Maintenance

477 F.A. van der Duyn Schouten, M.J.G. van Eijs, R.M.J. Heuts
Coordinated replenishment systems with discount opportunities

478 A. van den Nouweland, J. Potters, S. Tijs and J. Zarzuelo
Cores and related solution concepts for multi-choice games

479 Drs. C.H. Veld
Warrant pricing: a review of theoretical and empirical research

480 E. Nijssen
De Miles and Snow-typologie: Een exploratieve studie in de meubel-
branche

481 Harry G. Barkema
Are managers indeed motivated by their bonuses?
Jacob C. Engwerda, André C.M. Ran, Arie L. Rijkeboer
Necessary and sufficient conditions for the existence of a positive definite solution of the matrix equation $X + A^T X A = I$

Peter M. Kort
A dynamic model of the firm with uncertain earnings and adjustment costs

Raymond H.J.M. Gradus, Peter M. Kort
Optimal taxation on profit and pollution within a macroeconomic framework

Raymond H.J.M. Gradus, Peter M. Kort
Optimal taxation on profit and pollution within a macroeconomic framework

René van den Brink, Robert P. Gilles
Axiomatizations of the Conjunctive Permission Value for Games with Permission Structures

A.E. Brouwer & W.H. Haemers
The Gewirtz graph - an exercise in the theory of graph spectra

Pim Adang, Bertrand Melenberg
Intratemporal uncertainty in the multi-good life cycle consumption model: motivation and application

J.H.J. Roemen
The long term elasticity of the milk supply with respect to the milk price in the Netherlands in the period 1969-1984

Herbert Hamers
The Shapley-Entrance Game

Rezaul Kabir and Theo Vermaelen
Insider trading restrictions and the stock market

Piet A. Verheyen
The economic explanation of the jump of the co-state variable

Drs. F.L.J.W. Manders en Dr. J.A.C. de Haan
De organisatorische aspecten bij systeemontwikkeling een beschouwing op besturing en verandering

Paul C. van Batenburg and J. Kriens
Applications of statistical methods and techniques to auditing and accounting

Ruud T. Frambach
The diffusion of innovations: the influence of supply-side factors