# **ECONSTOR** Make Your Publications Visible.

A Service of

ZBW

Leibniz-Informationszentrum Wirtschaft Leibniz Information Centre for Economics

Biørn, Erik; Klette, Tor Jakob

## Working Paper — Digitized Version Panel Data with Errors-in-Variables: A Note on Essential and Redundant Orthogonality Conditions in GMMestimation

Discussion Papers, No. 190

**Provided in Cooperation with:** Research Department, Statistics Norway, Oslo

*Suggested Citation:* Biørn, Erik; Klette, Tor Jakob (1997) : Panel Data with Errors-in-Variables: A Note on Essential and Redundant Orthogonality Conditions in GMM-estimation, Discussion Papers, No. 190, Statistics Norway, Research Department, Oslo

This Version is available at: https://hdl.handle.net/10419/192174

#### Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

#### Terms of use:

Documents in EconStor may be saved and copied for your personal and scholarly purposes.

You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.

If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.



## WWW.ECONSTOR.EU

Statistics Norway Research Department

Erik Biørn and Tor Jakob Klette

Panel Data with Errors-in-Variables: A Note on Essential and Redundant Orthogonality Conditions in GMM-estimation

## Erik Biørn and Tor Jakob Klette

## Panel Data with Errors-in-Variables: A Note on Essential and Redundant Orthogonality Conditions in GMM-estimation

#### Abstract:

General Method of Moments (GMM) estimation of a linear one-equation model using panel data with errors-in-variables is considered. To eliminate fixed individual heterogeneity, the equation is differenced across one or more than one periods and estimated by means of instrumental variables. With non-autocorrelated measurement error, we show that only the one-period and a few two-period differences are essential, i.e. relevant for GMM-estimation. GMM estimation based on all orthogonality conditions on the basis of a generalized inverse formulation is shown to be equivalent to estimation using only the essential orthogonality conditions

Keywords: Panel Data, Errors-in-Variables, Instrumental Variables, GMM Estimation, Generalized inverse

JEL classification: C23, C33, C12, C13.

Address: Erik Biørn, University of Oslo, Department of Economics, P.O. Box 1095 Blindern, N-0317 Oslo, Norway E-mail: erik.biorn@econ.uio.no

> Tor Jakob Klette, Statistics Norway, Research Department, P.O.Box 8131 Dep., N-0033 Oslo, Norway. E-mail: tjk@ssb.no

#### 1 Introduction

Estimation and testing of econometric models for panel data by means of the Generalized Method of Moments (GMM) has received considerable attention in recent years; see Baltagi (1995, especially ch. 8) for a survey. GMM estimation can be used for consistent and asymptotically efficient estimation of linear equations with endogenous right-hand side variables, with lagged values of left-hand side variables as right-hand side variables, with random measurement errors in the right-hand side variables, and for some kinds of nonlinear models.

The focus in this paper is on the errors-in-variables problem for panel data in a single linear static equation context, although several of the procedures and the results below may also be made applicable to other, more complex, situations. A primary motivation of the paper is to elaborate the matrix algebra for GMM estimation of differenced equations and the associated orthogonality conditions in a panel data context in more detail than is commonly given in the literature, cf. e.g. Griliches and Hausman (1986). We specifically discuss a rank problem which arise when using GMM estimation of equations expressed as differences in an errors-in-variables context, when the various differenced equations and the associated orthogonality conditions are not linearly independent. This rank problem can be handled by either (i) replacing the standard inverses in the expressions for the GMM estimators by generalized (Moore-Penrose) inverses, or (ii) eliminating the redundant orthogonality conditions from the GMM procedure, as we prove to be equivalent and computationally more attractive.

## 2 Instrumental variable estimation for panel data with errorsin-variables.

#### 2.1 The basic model

Consider a balanced set of panel data for N units or groups in T successive periods and the relationship between a left-hand side variable y and a right-hand side variable x (both scalars). The analysis is limited to the case with only one regressor for convenience, as did Griliches and Hausman (1986), but the insights can be generalized rather straightforwardly to cases with several regressors. Let  $y_{it}$  and  $x_{it}$  denote their values for observation unit i (in the following denoted as individual i) in period t, satisfying

$$y_{it} = x_{it}\beta + a_i + u_{it}, \qquad i = 1, \dots, N; t = 1, \dots, T,$$
 (1)

where  $a_i$  is a fixed effect (including a common constant term), specific to individual i,  $\beta$  is an unknown scalar constant, and  $u_{it}$  is a zero mean, random disturbance/error term. We assume,

owing to endogeneity of  $x_{it}$  or random measurement error in  $x_{it}$ , (i) that  $u_{it}$  is correlated with  $x_{it}$ , (ii) that  $u_{it}$  is uncorrelated with  $u_{js}$  for all  $j \neq i$ , and (iii) that  $u_{it}$  is uncorrelated with  $x_{is}$  for all i and some  $s \neq t$ . We will mostly focus on the case where  $u_{it}$  is uncorrelated with  $u_{is}$  for all  $t \neq s$ , but we will discuss more general cases in section 3.3. It is convenient to rewrite (1) as N vector equations, one for each individual i:

$$\underline{y}_i = \underline{x}_i \beta + a_i \otimes e'_T + \underline{u}_i, \qquad i = 1, \dots, N.$$
(2)

where  $\underline{y}_i$ ,  $\underline{x}_i$  and  $\underline{u}_i$  are  $(1 \times T)$  vectors (with  $y_{it}$ ,  $x_{it}$  and  $u_{it}$  from individual *i* as elements),  $\otimes$  is the Kronecker product operator,  $a = (a_1 \cdots a_N)$  and  $e_T = (1 \cdots 1)'$  is a  $(T \times 1)$  vector of ones.

In order to eliminate  $a_i$  from (2), we will work with observations differenced across time periods. If T > 2, these differences can be taken across 1, 2, ..., T - 1 periods. To formalize this, we introduce the *differencing vectors* 

$$D_{ts} = \begin{bmatrix} (1 \times T) \text{ vector with} \\ \text{element } t = +1, \text{ element } s = -1, \\ \text{and zero otherwise} \end{bmatrix}, \quad t, s = 1, \dots, T; \ t > s, \quad (3)$$

where t > s can be assumed without loss of generality. Premultiplying a  $(T \times 1)$  vector by  $D_{ts}$ takes a difference between its t'th and s'th elements. Since there are  $S = \frac{1}{2}T(T-1)$  different ways of drawing two elements from T, there are S such  $D_{ts}$  vectors, among which T-1 take differences across one period, T-2 across two periods, ..., two across T-2 periods, and one across T-1periods. The differencing vectors are not independent, since all  $S - (T-1) = \frac{1}{2}(T-1)(T-2)$ differences over two or more periods can be constructed from the T-1 one-period differences, formally  $D_{ts} = \sum_{j=s+1}^{t} D_{j,j-1}$ , with t > s and  $t, s = 1, \ldots, T$ . Postmultiplying through (2) by  $D'_{ts}$ , recalling that  $D_{ts}e_T = 0$ , we get  $\underline{y}_i D'_{ts} = \underline{x}_i D'_{ts} \beta + \underline{u}_i D'_{ts}$ , or

$$y_{it} - y_{is} = (x_{it} - x_{is})\beta + (u_{it} - u_{is}), \qquad t, s = 1, \dots, T; \ t > s, \qquad (4)$$

Defining the stacked  $(S \times T)$  differencing matrix

$$D = \begin{bmatrix} D'_{21} & D'_{32} & \cdots & D'_{T,T-1} & D'_{31} & D'_{42} & \cdots & D'_{T,T-2} & \cdots & D'_{T1} \end{bmatrix}',$$
(5)

we can rewrite (4) as:

$$Y_i = X_i \beta + U_i, \qquad i = 1, \dots, N, \tag{6}$$

where

$$\begin{cases} Y_i = D \underline{y}'_i, \\ X_i = D \underline{x}'_i, \quad i = 1, \dots, N. \\ U_i = D \underline{u}'_i, \end{cases}$$

(6) may be considered a system of S equations with a common slope coefficient  $\beta$  and with N observations of each equation. When different pairs of periods are involved, we always assume that the pairs of periods (t, s) are ordered in the same way as in (5).

#### 2.2 Instrumental variables and the orthogonality conditions

The structural parameter  $\beta$  in the model can be estimated using lagged and leaded x's as instrumental variables if the measurement errors in the x's are non-autocorrelated, as was shown by Griliches and Hausman (1986). Specifically, if we consider (4) for two given periods t and s, valid instruments are  $x_{i\tau}$  for  $\tau \neq t, s$  ( $\tau = 1, ..., T$ )<sup>1</sup>. Consequently, we have different instruments for each of the S equations in (6), and consequently a GMM-procedure is called for to estimate  $\beta$  from the whole system of equations jointly.

The idea we follow is, for one pair of periods (t, s), to use as IV's all the T-2 elements of  $\underline{x}_i$ for the T-2 periods which are not used in the construction of the differenced variables in (4). A similar general idea has been followed in the literature on dynamic panel data models<sup>2</sup>, and by Griliches and Hausman (1986), for panel data models with errors in variables<sup>3</sup>. We define the  $S = \frac{1}{2}T(T-1)$  selection matrices

$$P_{ts} = \begin{bmatrix} ((T-2) \times T) \text{ matrix} \\ \text{obtained by deleting} \\ \text{rows } s \text{ and } t \text{ from } I_T \end{bmatrix}, \quad t, s = 1, \dots, T; \ t > s, \tag{7}$$

and

$$z_{its} = \underline{x}_i P'_{ts} = \begin{bmatrix} (1 \times (T-2)) \text{ vector} \\ \text{obtained by deleting} \\ \text{elements } s \text{ and } t \text{ from } \underline{x}_i \end{bmatrix}, \quad \begin{array}{l} i = 1, \dots, N; \\ t, s = 1, \dots, T; \\ t > s. \end{array}$$
(8)

To carry out GMM estimation of  $\beta$  based on the complete system of S equations, we must stack the instruments as follows. Define the  $(S \times S(T-2))$  IV matrix for individual i

$$Z_{i} = \begin{bmatrix} z_{i21} & 0 & \cdots & 0 \\ 0 & z_{i32} & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & z_{iT1} \end{bmatrix} = \begin{bmatrix} \underline{x}_{i}P'_{21} & 0 & \cdots & 0 \\ 0 & \underline{x}_{i}P'_{32} & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & \underline{x}_{i}P'_{T1} \end{bmatrix},$$

which can be written as

$$Z_i = (I_S \otimes \underline{x}_i) P', \qquad (9)$$

that  $p \lim_{N \to \infty} [(1/N) \sum_{i=1}^{N} x_{i\tau} (x_{it} - x_{is})]$ <sup>1</sup>This requires, 0 in addition to of course, ¥  $p \lim_{N \to \infty} [(1/N) \sum_{i=1}^{N} x_{i\tau} (u_{it} - u_{is})] \neq 0.$ <sup>2</sup>See Baltagi (1995, chapter 8) for a survey.

<sup>&</sup>lt;sup>3</sup>See also Biørn (1996, section 10.2.3).

where P is the  $(S(T-2) \times ST)$  matrix, containing only zeros and ones,

$$P = \begin{bmatrix} P_{21} & 0 & \cdots & 0 \\ 0 & P_{32} & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & P_{T1} \end{bmatrix}.$$
 (10)

Premultiplying (6) by  $Z'_i$ , we get

$$Z'_{i}Y_{i} = Z'_{i}X_{i}\beta + Z'_{i}U_{i}, \qquad i = 1, \dots, N.$$
(11)

The orthogonality conditions which are a priori relevant to GMM estimation of  $\beta$  based on (11) can be stated:

$$\mathcal{E}(Z'_i U_i) = \underline{0}, \qquad i = 1, \dots, N.$$
(12)

where  $\underline{0}$  is a  $(S(T-2) \times 1)$  vector of zeros, i.e. (12) represents S(T-2) scalar orthogonality conditions.

#### 2.3 The GMM-estimator and the generalized inverse

Some of the elements in the (vector) equation (12) are redundant, as they do not contain additional information. This can be seen by noticing that for say l < s (or l > t) we have that

$$\mathcal{E}[x_{il}(u_{it} - u_{is})] = \mathcal{E}[x_{il}(u_{i,s+1} - u_{is})] + \dots + \mathcal{E}[x_{il}(u_{it} - u_{i,t-1})].$$
(13)

That is, the orthogonality condition  $\mathcal{E}[x_{il}(u_{it} - u_{is})] = 0$  can be constructed as a simple sum of the orthogonality conditions on the right hand side of (13). As a consequence, the variancecovariance matrix needed for GMM estimation on the basis of (11) and (12) does not have full rank. We will elaborate on this point below.

Denote the (reduced rank) variance-covariance matrix associated with (12) by  $\Omega_i$ , i.e.

$$\Omega_i = \mathcal{E}(Z_i' \, U_i \, U_i' Z_i). \tag{14}$$

White (1986) has considered efficient estimation based on orthogonality conditions such as (12), in the general case where  $\Omega_i$  might not have full rank. Using Theorem 3.2 in White, we find that the asymptotically efficient GMM estimator  $\hat{\beta}$ , based on the orthogonality conditions (12) for i = 1, ..., N, can be written:

$$\widehat{\beta} = \left[ \left( \sum_{i} X_{i}^{\prime} Z_{i} \right) \left( \sum_{i} \Omega_{i} \right)^{+} \left( \sum_{i} Z_{i}^{\prime} X_{i} \right) \right]^{-1} \left( \sum_{i} X_{i}^{\prime} Z_{i} \right) \left( \sum_{i} \Omega_{i} \right)^{+} \left( \sum_{i} Z_{i}^{\prime} Y_{i} \right), \quad (15)$$

where the sums cover all individuals and  $(\sum_i \Omega_i)^+$  is the generalized inverse of  $\sum_i \Omega_i$ .

#### **3** Identification of essential orthogonality conditions

#### 3.1 The essential orthogonality conditions

Even though the estimator (15) is efficient in a statistical sense, it is not very efficient in a computational sense. Computationally it is more efficient to consider only the essential orthogonality conditions, which we will now identify. In the case with non-autocorrelated errors  $u_{it}$ , we show formally below that all orthogonality conditions can be constructed as simple sums of (i) all admissible orthogonality conditions based on one-period differences and (ii) a specific subset of the admissible orthogonality conditions based on two-period differences. All the other orthogonality conditions can be ignored.

The orthogonality conditions (12) are based on expressions of the form  $\mathcal{E}[x_{il}(u_{it} - u_{is})] = 0$ where  $l \neq t, s$ . However, all these orthogonality conditions can be constructed as simple sums of

(i) 
$$\mathcal{E}[x_{il}(u_{it} - u_{i,t-1})] = 0, l \neq t, t-1$$

(ii) 
$$\mathcal{E}[x_{il}(u_{i,l+1}-u_{i,l-1})]=0.$$

This is easily seen as follows: First, when  $l \notin [s, s + 1, ...t - 1, t]$ , any orthogonality condition  $\mathcal{E}[x_{il}(u_{it} - u_{is})] = 0$  can be constructed on the basis of expressions as in (i), using the identity

$$\mathcal{E}\left[x_{il}(u_{it}-u_{is})
ight] = \sum_{ au=s+1}^t \mathcal{E}\left[x_{il}(u_{i au}-u_{i, au-1})
ight].$$

Second, when  $l \in [s + 1, s + 2, ..., t - 2, t - 1]$ , expressions both of the forms (i) and (ii) must be combined, using

$$\mathcal{E}\left[x_{il}(u_{it}-u_{is})\right] = \sum_{\tau=l+2}^{t} \mathcal{E}\left[x_{il}(u_{i\tau}-u_{i,\tau-1})\right] + \mathcal{E}\left[x_{il}(u_{i,l+1}-u_{i,l-1})\right] + \sum_{\tau=s+1}^{l-1} \mathcal{E}\left[x_{il}(u_{i\tau}-u_{i,\tau-1})\right],$$

since  $\mathcal{E}[x_{il}(u_{il} - u_{i,l-1})] = 0$  and  $\mathcal{E}[x_{il}(u_{i,l+1} - u_{il})] = 0$  are inadmissible whereas  $\mathcal{E}[x_{il}(u_{i,l+1} - u_{i,l-1})] = 0$  is admissible. Hence, any orthogonality condition of the form  $\mathcal{E}[x_{il}(u_{it} - u_{is})] = 0$  where  $l \neq (t, s)$ , can be constructed from the two kinds of orthogonality conditions (i) and (ii).

It follows that the number of essential orthogonality conditions is T(T-2), while the total number of orthogonality conditions is T(T-1)(T-2)/2. Hence, only a fraction 2/(T-1) of the complete set of orthogonality conditions are essential. E.g., for T = 9, this fraction is one fourth.

We have shown that only orthogonality conditions based on the one-period and a few twoperiod differences are essential. We refer to the other orthogonality conditions as redundant. With autocorrelated noise, higher order differences replace the two-period differences; see Biørn and Klette (1997).

<sup>&</sup>lt;sup>4</sup>Among these, (T-1)(T-2) are based on one-period differences, and (T-2) on two-period differences.

#### 3.2 The equivalence of the two GMM-estimators

It follows from section 3.1 that there exists a matrix H of zeros and ones such that

$$\left[Z_i'U_i\right]_R = H\left[Z_i'U_i\right]_E,\tag{16}$$

where subscripts R and E denote the elements associated with the sets of redundant and essential orthogonality conditions respectively. More generally, we have

$$\left[ (Z_i'Y)_R \ (Z_i'X_i)_R \ (Z_i'U_i)_R \right] = H \left[ (Z_i'Y)_E \ (Z_i'X_i)_E \ (Z_i'U_i)_E \right].$$
(17)

Define

$$K = \left[ \begin{array}{c} I_{T(T-2)} \\ H \end{array} \right],$$

where  $I_{T(T-2)}$  is the identitity matrix of order T(T-2). Stacking  $Z'_iU_i$  as follows

$$Z'_i U_i = \left[ \begin{array}{c} (Z'_i U_i)_E \\ (Z'_i U_i)_R \end{array} \right],$$

and using (16), we have

$$\Omega_{i} = \mathcal{E} \left[ Z'_{i} U_{i} U'_{i} Z_{i} \right]$$
  
$$= K \mathcal{E} \left[ (Z'_{i} U_{i})_{E} (U'_{i} Z_{i})_{E} \right] K'$$
  
$$= K \Omega_{E,i} K'$$
(18)

where  $\Omega_{E,i}$  is defined by the last equality. Using (17) and (18), the GMM estimator in (15) can be rewritten

$$\widehat{\beta} = \left\{ \left( \sum_{i} X_{i}^{\prime} Z_{i} \right)_{E} K^{\prime} \left[ K \left( \sum_{i} \Omega_{E,i} \right) K^{\prime} \right]^{+} K \left( \sum_{i} Z_{i}^{\prime} X_{i} \right)_{E} \right\}^{-1} \times \left( \sum_{i} X_{i}^{\prime} Z_{i} \right)_{E} K^{\prime} \left[ K \left( \sum_{i} \Omega_{E,i} \right) K^{\prime} \right]^{+} K \left( \sum_{i} Z_{i}^{\prime} Y_{i} \right)_{E}.$$
(19)

The definition of the generalized inverse implies

$$(K\Omega_E K')(K\Omega_E K')^+(K\Omega_E K') = (K\Omega_E K'),$$

where we have used  $\Omega_E$  as a short-hand notation for  $\sum_i \Omega_{E,i}$ . Pre- and postmultiplying this equation by  $\Omega_E^{-1}(K'K)^{-1}K'$  and  $K(K'K)^{-1}\Omega_E^{-1}$  respectively, we find that

$$K'(K\Omega_E K')^+ K = \Omega_E^{-1}.$$
(20)

Inserting (20) into (19), we find that

$$\widehat{\beta} = \left[ \left( \sum_{i} X_{i}^{\prime} Z_{i} \right)_{E} \left( \sum_{i} \Omega_{E,i} \right)^{-1} \left( \sum_{i} Z_{i}^{\prime} X_{i} \right)_{E} \right]^{-1} \left( \sum_{i} X_{i}^{\prime} Z_{i} \right)_{E} \left( \sum_{i} \Omega_{E,i} \right)^{-1} \left( \sum_{i} Z_{i}^{\prime} Y_{i} \right)_{E}$$

Hence, the GMM-estimator based on the complete set of orthogonality conditions is *equivalent* to the GMM-estimator based on only the essential orthogonality conditions.

As remarked above, the essential set of orthogonality conditions constitutes a fraction 2/(T-1) of the complete set of orthogonality conditions. Exploiting only the former can reduce the computational burden considerably, in particular related to inverting the variance-covariance matrix  $(\sum_i \Omega_i)$ . With a moderately long panel such as T = 9, using the complete set of orthogonality conditions, this matrix has dimension  $(252 \times 252)$ , which is reduced to  $(63 \times 63)$  when using only the essential orthogonality conditions.

Here we should point out that with more than one regressor, say G regressors, the dimensionality of the IV matrix  $Z_i$  and hence the variance-covariance matrix  $\Omega_i$  will grow in proportion to G, while the fraction 2/(T-1) of the complete set of orthogonality conditions that is essential remains the same. Hence, with G = 3 and T = 9,  $\Omega_i$  will have dimension (756 × 756), while  $\Omega_{E,i}$ has dimension (189 × 189). Whether it is a good idea in practice to use all essential orthogonality conditions (as defined above) with T = 9 and G = 3 depends on the sample size and the stochastic processes for the regressors. However, these are issues discussed elsewhere under the labels "overfitting" and "weak instruments"; see e.g. Davidson and MacKinnon (1993, chs. 7 and 17) and Staiger and Stock (1994, 1996).

In Biørn and Klette (1997) we elaborate on the analysis above and show, in particular, how to identify the essential orthogonality conditions in cases with autocorrelated measurement errors.

#### 4 Final remarks

This note has examined the orthogonality conditions relevant for GMM estimation of differenced equations from panel data with errors-in-variables, using variables in levels as IVs for differenced variables. We have shown that with non-autocorrelated measurement errors, only a small fraction of the potential orthogonality conditions are essential, namely those based on one-period and a few two-period differences. When only predetermined variables are valid instruments as in *autoregressive* panel data models, even the two-period differences are inadmissible, and one is left only with the orthogonality conditions based on one-period differences.

### References

Baltagi, B.H. (1995): Econometric analysis of panel data, New York: Wiley Publ. co.

- Biørn, E. (1996): Panel data with measurement errors. Chapter 10 in L.Matyas and P. Sevestre (eds.): The econometrics of panel data. Handbook of the theory with applications. Dordrecht: Kluwer.
- Biørn, E. and T.J. Klette (1997): Variable differencing and GMM estimation with panel data with errors-in-variables, Mimeo.
- Davidson, R. and J.G. MacKinnon (1993): Estimation and inference in econometrics, Oxford: Oxford University Press.
- Griliches, Z. and J.A. Hausman (1986): Errors in variables in panel data, Journal of Econometrics 18, 93-118.
- Staiger, D. and J.H. Stock (1994): Instrumental variable regression with weak instruments, NBER Technical Working Paper no. 151.
- Staiger, D. and J.H. Stock (1996): Asymptotics for GMM estimators with weak instruments, NBER Technical Working Paper no. 198.
- White, H. (1986): Instrumental variables analogs of generalized least squares estimators, Advances in Statistical Analysis and Statistical Computing 1, 173-227.

#### **Recent publications in the series Discussion Papers**

- 43 K.A. Mork, H.T. Mysen and Ø. Olsen (1989): Business Cycles and Oil Price Fluctuations: Some evidence for six OECD countries.
- 44 B. Bye, T. Bye and L. Lorentsen (1989): SIMEN. Studies of Industry, Environment and Energy towards 2000.
- 45 O. Bjerkholt, E. Gjelsvik and Ø. Olsen (1989): Gas Trade and Demand in Northwest Europe: Regulation, Bargaining and Competition.
- 46 L.S. Stambøl and K.Ø. Sørensen (1989): Migration Analysis and Regional Population Projections.
- 47 V. Christiansen (1990): A Note on the Short Run Versus Long Run Welfare Gain from a Tax Reform.
- 48 S. Glomsrød, H. Vennemo and T. Johnsen (1990): Stabilization of Emissions of CO<sub>2</sub>: A Computable General Equilibrium Assessment.
- 49 J. Aasness (1990): Properties of Demand Functions for Linear Consumption Aggregates.
- 50 J.G. de Leon (1990): Empirical EDA Models to Fit and Project Time Series of Age-Specific Mortality Rates.
- 51 J.G. de Leon (1990): Recent Developments in Parity Progression Intensities in Norway. An Analysis Based on Population Register Data
- 52 R. Aaberge and T. Wennemo (1990): Non-Stationary Inflow and Duration of Unemployment
- 53 R. Aaberge, J.K. Dagsvik and S. Strøm (1990): Labor Supply, Income Distribution and Excess Burden of Personal Income Taxation in Sweden
- 54 R. Aaberge, J.K. Dagsvik and S. Strøm (1990): Labor Supply, Income Distribution and Excess Burden of Personal Income Taxation in Norway
- 55 H. Vennemo (1990): Optimal Taxation in Applied General Equilibrium Models Adopting the Armington Assumption
- 56 N.M. Stølen (1990): Is there a NAIRU in Norway?
- 57 Å. Cappelen (1991): Macroeconomic Modelling: The Norwegian Experience
- 58 J.K. Dagsvik and R. Aaberge (1991): Household Production, Consumption and Time Allocation in Peru
- 59 R. Aaberge and J.K. Dagsvik (1991): Inequality in Distribution of Hours of Work and Consumption in Peru
- 60 T.J. Klette (1991): On the Importance of R&D and Ownership for Productivity Growth. Evidence from Norwegian Micro-Data 1976-85
- 61 K.H. Alfsen (1991): Use of Macroeconomic Models in Analysis of Environmental Problems in Norway and Consequences for Environmental Statistics
- 62 H. Vennemo (1991): An Applied General Equilibrium Assessment of the Marginal Cost of Public Funds in Norway
- 63 H. Vennemo (1991): The Marginal Cost of Public Funds: A Comment on the Literature
- 64 A. Brendemoen and H. Vennemo (1991): A climate convention and the Norwegian economy: A CGE assessment
- 65 K.A. Brekke (1991): Net National Product as a Welfare Indicator
- 66 E. Bowitz and E. Storm (1991): Will Restrictive Demand Policy Improve Public Sector Balance?
- 67 Å. Cappelen (1991): MODAG. A Medium Term Macroeconomic Model of the Norwegian Economy

- 68 B. Bye (1992): Modelling Consumers' Energy Demand
- 69 K.H. Alfsen, A. Brendemoen and S. Glomsrød (1992): Benefits of Climate Policies: Some Tentative Calculations
- 70 R. Aaberge, Xiaojie Chen, Jing Li and Xuezeng Li (1992): The Structure of Economic Inequality among Households Living in Urban Sichuan and Liaoning, 1990
- 71 K.H. Alfsen, K.A. Brekke, F. Brunvoll, H. Lurås, K. Nyborg and H.W. Sæbø (1992): Environmental Indicators
- 72 B. Bye and E. Holmøy (1992): Dynamic Equilibrium Adjustments to a Terms of Trade Disturbance
- 73 O. Aukrust (1992): The Scandinavian Contribution to National Accounting
- 74 J. Aasness, E. Eide and T. Skjerpen (1992): A Criminometric Study Using Panel Data and Latent Variables
- 75 R. Aaberge and Xuezeng Li (1992): The Trend in Income Inequality in Urban Sichuan and Liaoning, 1986-1990
- 76 J.K. Dagsvik and S. Strøm (1992): Labor Supply with Non-convex Budget Sets, Hours Restriction and Nonpecuniary Job-attributes
- 77 J.K. Dagsvik (1992): Intertemporal Discrete Choice, Random Tastes and Functional Form
- 78 H. Vennemo (1993): Tax Reforms when Utility is Composed of Additive Functions
- 79 J.K. Dagsvik (1993): Discrete and Continuous Choice, Max-stable Processes and Independence from Irrelevant Attributes
- 80 J.K. Dagsvik (1993): How Large is the Class of Generalized Extreme Value Random Utility Models?
- 81 H. Birkelund, E. Gjelsvik, M. Aaserud (1993): Carbon/ energy Taxes and the Energy Market in Western Europe
- 82 E. Bowitz (1993): Unemployment and the Growth in the Number of Recipients of Disability Benefits in Norway
- 83 L. Andreassen (1993): Theoretical and Econometric Modeling of Disequilibrium
- 84 K.A. Brekke (1993): Do Cost-Benefit Analyses favour Environmentalists?
- 85 L. Andreassen (1993): Demographic Forecasting with a Dynamic Stochastic Microsimulation Model
- 86 G.B. Asheim and K.A. Brekke (1993): Sustainability when Resource Management has Stochastic Consequences
- 87 O. Bjerkholt and Yu Zhu (1993): Living Conditions of Urban Chinese Households around 1990
- 88 R. Aaberge (1993): Theoretical Foundations of Lorenz Curve Orderings
- 89 J. Aasness, E. Biørn and T. Skjerpen (1993): Engel Functions, Panel Data, and Latent Variables - with Detailed Results
- 90 I. Svendsen (1993): Testing the Rational Expectations Hypothesis Using Norwegian Microeconomic Data Testing the REH. Using Norwegian Microeconomic Data
- 91 E. Bowitz, A. Rødseth and E. Storm (1993): Fiscal Expansion, the Budget Deficit and the Economy: Norway 1988-91

- 92 R. Aaberge, U. Colombino and S. Strøm (1993): Labor Supply in Italy
- 93 T.J. Klette (1993): Is Price Equal to Marginal Costs? An Integrated Study of Price-Cost Margins and Scale Economies among Norwegian Manufacturing Establishments 1975-90
- 94 J.K. Dagsvik (1993): Choice Probabilities and Equilibrium Conditions in a Matching Market with Flexible Contracts
- 95 T. Kornstad (1993): Empirical Approaches for Analysing Consumption and Labour Supply in a Life Cycle Perspective
- 96 T. Kornstad (1993): An Empirical Life Cycle Model of Savings, Labour Supply and Consumption without Intertemporal Separability
- 97 S. Kverndokk (1993): Coalitions and Side Payments in International CO<sub>2</sub> Treaties
- 98 T. Eika (1993): Wage Equations in Macro Models. Phillips Curve versus Error Correction Model Determination of Wages in Large-Scale UK Macro Models
- 99 A. Brendemoen and H. Vennemo (1993): The Marginal Cost of Funds in the Presence of External Effects
- 100 K.-G. Lindquist (1993): Empirical Modelling of Norwegian Exports: A Disaggregated Approach
- 101 A.S. Jore, T. Skjerpen and A. Rygh Swensen (1993): Testing for Purchasing Power Parity and Interest Rate Parities on Norwegian Data
- 102 R. Nesbakken and S. Strøm (1993): The Choice of Space Heating System and Energy Consumption in Norwegian Households (Will be issued later)
- 103 A. Aaheim and K. Nyborg (1993): "Green National Product": Good Intentions, Poor Device?
- 104 K.H. Alfsen, H. Birkelund and M. Aaserud (1993): Secondary benefits of the EC Carbon/ Energy Tax
- 105 J. Aasness and B. Holtsmark (1993): Consumer Demand in a General Equilibrium Model for Environmental Analysis
- 106 K.-G. Lindquist (1993): The Existence of Factor Substitution in the Primary Aluminium Industry: A Multivariate Error Correction Approach on Norwegian Panel Data
- 107 S. Kverndokk (1994): Depletion of Fossil Fuels and the Impacts of Global Warming
- 108 K.A. Magnussen (1994): Precautionary Saving and Old-Age Pensions
- 109 F. Johansen (1994): Investment and Financial Constraints: An Empirical Analysis of Norwegian Firms
- 110 K.A. Brekke and P. Børing (1994): The Volatility of Oil Wealth under Uncertainty about Parameter Values
- 111 M.J. Simpson (1994): Foreign Control and Norwegian Manufacturing Performance
- 112 Y. Willassen and T.J. Klette (1994): Correlated Measurement Errors, Bound on Parameters, and a Model of Producer Behavior
- 113 D. Wetterwald (1994): Car ownership and private car use. A microeconometric analysis based on Norwegian data
- 114 K.E. Rosendahl (1994): Does Improved Environmental Policy Enhance Economic Growth? Endogenous Growth Theory Applied to Developing Countries
- 115 L. Andreassen, D. Fredriksen and O. Ljones (1994): The Future Burden of Public Pension Benefits. A Microsimulation Study

- 116 A. Brendemoen (1994): Car Ownership Decisions in Norwegian Households.
- 117 A. Langørgen (1994): A Macromodel of Local Government Spending Behaviour in Norway
- 118 K.A. Brekke (1994): Utilitarism, Equivalence Scales and Logarithmic Utility
- 119 K.A. Brekke, H. Lurås and K. Nyborg (1994): Sufficient Welfare Indicators: Allowing Disagreement in Evaluations of Social Welfare
- 120 T.J. Klette (1994): R&D, Scope Economies and Company Structure: A "Not-so-Fixed Effect" Model of Plant Performance
- 121 Y. Willassen (1994): A Generalization of Hall's Specification of the Consumption function
- 122 E. Holmøy, T. Hægeland and Ø. Olsen (1994): Effective Rates of Assistance for Norwegian Industries
- 123 K. Mohn (1994): On Equity and Public Pricing in Developing Countries
- 124 J. Aasness, E. Eide and T. Skjerpen (1994): Criminometrics, Latent Variables, Panel Data, and Different Types of Crime
- 125 E. Biørn and T.J. Klette (1994): Errors in Variables and Panel Data: The Labour Demand Response to Permanent Changes in Output
- 126 I. Svendsen (1994): Do Norwegian Firms Form Extrapolative Expectations?
- 127 T.J. Klette and Z. Griliches (1994): The Inconsistency of Common Scale Estimators when Output Prices are Unobserved and Endogenous
- 128 K.E. Rosendahl (1994): Carbon Taxes and the Petroleum Wealth
- 129 S. Johansen and A. Rygh Swensen (1994): Testing Rational Expectations in Vector Autoregressive Models
- 130 T.J. Klette (1994): Estimating Price-Cost Margins and Scale Economies from a Panel of Microdata
- 131 L. A. Grünfeld (1994): Monetary Aspects of Business Cycles in Norway: An Exploratory Study Based on Historical Data
- 132 K.-G. Lindquist (1994): Testing for Market Power in the Norwegian Primary Aluminium Industry
- 133 T. J. Klette (1994): R&D, Spillovers and Performance among Heterogenous Firms. An Empirical Study Using Microdata
- 134 K.A. Brekke and H.A. Gravningsmyhr (1994): Adjusting NNP for instrumental or defensive expenditures. An analytical approach
- 135 T.O. Thoresen (1995): Distributional and Behavioural Effects of Child Care Subsidies
- 136 T. J. Klette and A. Mathiassen (1995): Job Creation, Job Destruction and Plant Turnover in Norwegian Manufacturing
- 137 K. Nyborg (1995): Project Evaluations and Decision Processes
- 138 L. Andreassen (1995): A Framework for Estimating Disequilibrium Models with Many Markets
- 139 L. Andreassen (1995): Aggregation when Markets do not Clear
- 140 T. Skjerpen (1995): Is there a Business Cycle Component in Norwegian Macroeconomic Quarterly Time Series?
- 141 J.K. Dagsvik (1995): Probabilistic Choice Models for Uncertain Outcomes

- 142 M. Rønsen (1995): Maternal employment in Norway, A Parity-Specific Analysis of the Return to Full-Time and Part-Time Work after Birth
- 143 A. Bruvoll, S. Glomsrød and H. Vennemo (1995): The Environmental Drag on Long- Term Economic Performance: Evidence from Norway
- 144 T. Bye and T. A. Johnsen (1995): Prospects for a Common, Deregulated Nordic Electricity Market
- 145 B. Bye (1995): A Dynamic Equilibrium Analysis of a Carbon Tax
- 146 T. O. Thoresen (1995): The Distributional Impact of the Norwegian Tax Reform Measured by Disproportionality
- 147 E. Holmøy and T. Hægeland (1995): Effective Rates of Assistance for Norwegian Industries
- 148 J. Aasness, T. Bye and H.T. Mysen (1995): Welfare Effects of Emission Taxes in Norway
- 149 J. Aasness, E. Biørn and Terje Skjerpen (1995): Distribution of Preferences and Measurement Errors in a Disaggregated Expenditure System
- 150 E. Bowitz, T. Fæhn, L. A. Grünfeld and K. Moum (1995): Transitory Adjustment Costs and Long Term Welfare Effects of an EU-membership – The Norwegian Case
- 151 I. Svendsen (1995): Dynamic Modelling of Domestic Prices with Time-varying Elasticities and Rational Expectations
- 152 I. Svendsen (1995): Forward- and Backward Looking Models for Norwegian Export Prices
- 153 A. Langørgen (1995): On the Simultaneous Determination of Current Expenditure, Real Capital, Fee Income, and Public Debt in Norwegian Local Government
- 154 A. Katz and T. Bye(1995): Returns to Publicly Owned Transport Infrastructure Investment. A Cost Function/ Cost Share Approach for Norway, 1971-1991
- 155 K. O. Aarbu (1995): Some Issues About the Norwegian Capital Income Imputation Model
- 156 P. Boug, K. A. Mork and T. Tjemsland (1995): Financial Deregulation and Consumer Behavior: the Norwegian Experience
- 157 B.E. Naug and R. Nymoen (1995): Import Price Formation and Pricing to Market: A Test on Norwegian Data
- 158 R. Aaberge (1995): Choosing Measures of Inequality for Empirical Applications
- 159 T.J. Klette and S.E. Førre (1995): Innovation and Job Creation in a Small Open Economy: Evidence from Norwegian Manufacturing Plants 1982-92
- 160 S. Holden, D. Kolsrud and B. Vikøren (1995): Noisy Signals in Target Zone Regimes: Theory and Monte Carlo Experiments
- 161 T. Hægeland (1996): Monopolistic Competition, Resource Allocation and the Effects of Industrial Policy
- 162 S. Grepperud (1996): Poverty, Land Degradation and Climatic Uncertainty
- 163 S. Grepperud (1996): Soil Conservation as an Investment in Land
- 164 K.A. Brekke, V. Iversen and J. Aune (1996): Soil Wealth in Tanzania
- 165 J.K. Dagsvik, D.G. Wetterwald and R. Aaberge (1996): Potential Demand for Alternative Fuel Vehicles
- 166 J.K. Dagsvik (1996): Consumer Demand with Unobservable Product Attributes. Part I: Theory

- 167 J.K. Dagsvik (1996): Consumer Demand with Unobservable Product Attributes. Part II: Inference
- 168 R. Aaberge, A. Björklund, M. Jäntti, M. Palme, P. J. Pedersen, N. Smith and T. Wennemo (1996): Income Inequality and Income Mobility in the Scandinavian Countries Compared to the United States
- 169 K. Nyborg (1996): Some Norwegian Politicians' Use of Cost-Benefit Analysis
- 170 E. Berg, S. Kverndokk and K. E. Rosendahl (1996): Market Power, International CO<sub>2</sub> Taxation and Petroleum Wealth
- 171 R. Aaberge, U. Colombino and S. Strøm (1996): Welfare Effects of Proportional Taxation: Empirical Evidence from Italy, Norway and Sweden
- 172 J.K. Dagsvik (1996): Dynamic Choice, Multistate Duration Models and Stochastic Structure
- 173 J.K. Dagsvik (1996): Aggregation in Matching Markets
- 174 H.C. Bjørnland (1996): The Dynamic Effects of Aggregate Demand, Supply and Oil Price Shocks
- 175 A. Bruvoll and K. Ibenholt (1996): Future Waste Generation. Forecasts Based on a Macroeconomic Model
- 176 T. Fæhn and L. A. Grünfeld (1996) Recent Leaps Towards Free Trade. The Impact on Norwegian Industry and Trade Patterns
- 177 R. Barrell and K. A. Magnussen (1996): Counterfactual Analyses of Oil price Shocks using a World Model
- 178 E. Bowitz and S. I. Hove (1996): Business cycles and fiscal policy: Norway 1973-93
- 179 H.C. Bjørnland (1996): Sources of Business Cycles in Energy Producing Economies: The case of Norway and United Kingdom
- 180 K. Nyborg (1996): The Political Man and Contingent Valuation: Motives Do Count
- 181 E. Berg, S. Kverndokk and K.E. Rosendahl (1996): Gains from Cartelisation in the Oil Market
- 182 R. Aaberge and I. Aslaksen (1996): Decomposition of the Gini Coefficient by Income Components: Various Types of Applications and Interpretations
- 183 B. Bye (1996): Taxation, Unemployment and Growth: Dynamic Welfare Effects of "Green" Policies
- 184 T.J. Klette and F. Johansen (1996): Accumulation of R&D Capital and Dynamic Firm Performance: A Notso-fixed Effect Model
- 185 B. Bye (1996): Environmental Tax Reform and Producer Foresight: An Intertemporal Computable General Equilibrium Analysis
- 186 S. Grepperud (1997): Soil Depletion Choices under Production and Price Uncertainty
- 187 N.M. Stølen and T. Åvitsland (1997): Has Growth in Supply of Educated Persons Been Important for the Composition of Employment?
- 188 T.J. Klette and Z. Griliches (1997): Empirical Patterns of Firm Growth and R&D Investment: a Quality Ladder Model Interpretation
- 189 J. Aune, S. Glomsrød, V. Iversen and H. Wiig (1997): Structural Adjustment and Soil Degradation in Tanzania. A CGE-model Approach with Endogenous Soil Productivity
- 190 Erik Biørn and Tor Jakob Klette (1997): Panel Data with Errors-in-Variables: A Note on Essential and Redundant Orthogonality Conditions in GMM-estimation



Returadresse: Statistisk sentralbyrå Postboks 8131 Dep. N-0033 Oslo

Statistics Norway Research Department P.O.B. 8131 Dep. N-0033 Oslo

Tel.: + 47 - 22 86 45 00 Fax: + 47 - 22 11 12 38

ISSN 0803-074X

