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**Conference Paper**

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38th Congress of the European Regional Science Association: "Europe Quo Vadis? - Regional Questions at the Turn of the Century", 28 August - 1 September 1998, Vienna, Austria

**Provided in Cooperation with:**

European Regional Science Association (ERSA)

*Suggested Citation:* Lauridsen, Jorgen; Nahrstedt, Birgit (1998) : Spatial patterns in intermunicipal Danish commuting, 38th Congress of the European Regional Science Association: "Europe Quo Vadis? - Regional Questions at the Turn of the Century", 28 August - 1 September 1998, Vienna, Austria, European Regional Science Association (ERSA), Louvain-la-Neuve

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# **Spatial patterns in intermunicipal Danish commuting.**

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Paper to be written as part of the research project "Heterogeneity in Spatial Econometric Modeling". This version is intended for presentation at the 38th Congress of the European Regional Science Association, Vienna, Austria, August 28 - September 1, 1998.

## **Abstract.**

Intermunicipal variations in in-commuting are mainly explained by variations in number of workplaces, urbanization degree and wealth, whereas variations in out-commuting are mainly determined by variations in workforce size, number of workplaces, living patterns and unemployment. This is quite satisfactory according to existing theory.

However, of these explanatory factors only the number of workplaces influences the net in-commuting. But by using spatial lag structures it is shown that unemployment in neighbourhood municipalities influences net in-commuting.

Finally, evidence of impact of local spatial industrial patterns on the commuting behaviour is provided, and the nature and reasons for these spatial patterns are discussed.

## **1. Introduction.**

In some sense, the world has become smaller. As it until half a century ago was commonly accepted that people lived and worked in the same locality, it has become a widespread feature to have distances between workplace and home. Tkocz and Kristensen (1994) report average commuting distances for employees from a number of Danish cities ranging from 7 to 21 kilometres. Comparing this to the average size of Danish municipalities of 157 square kilometres, i.e. an average circular radius of 7 kilometres, the prevalence of commuting becomes evident.

An increasing amount of commuting has been facilitated by technological conquests in the form of refined infrastructure and faster and more comfortable modes of transport (Kristensen 1997). Further, commuting has been necessitated by specific spatial patterns of industries which contradict the spatial patterns in peoples preferences for living places. Many people - especially when educated - prefer to live in recreative areas away from city centres (Graversen, Hummelgaard and Nielsen 1997, Kristensen 1997). On the other hand, rural areas with low wages are preferred locations for many industrial branches whereas other branches seem to prefer urban areas (Kristensen 1997). Further, some cross-border studies (De Falleur and Vanderville 1994, Bacher, Kjølner and Mohr 1995, Hansen and Schack 1997) indicate that people commute from areas with low wages and high unemployment to areas with higher wages, lower unemployment and more prosperous industrial structure. These studies, too, indicate that house prices, rents for flats as well as amenities causes people to live away from urban areas where these are relatively high.

Commuting emerges from contradictions between the industrial localization preferences and the preference - and need driven choices of residences made by the workforce. To this point, the literature has been able to provide empirical evidence on the living place choice and commuting behaviour of the workforce, but no significant empirical findings has been provided on the nature and impact of industrial localization. For the case of Denmark, this shortcoming is due to a lack of data on a municipal base, as such data are mainly provided on an aggregated county level. The present paper intends to fill this gap, using spatial autoregressive and spatial Durbin model specifications. Specifically, the impact of workforce characteristics on in- and out-commuting will be measured using a causal linear regression specification. In this specification, the impact of spatial patterns outside the model - i.e. industrial clustering patterns - will be traced by adding spatial autoregressive and spatial Durbin processes.

## **2. Model suggestions for commuting in Denmark.**

The aim of the present study is to investigate the importance of various determinants for the intermunicipal commuting variations between the 275 Danish municipalities. To facilitate a detailed investigation of these determinants, the out-commuting and the in-commuting as well as the net (in-) commuting are analyzed. Following suggestions from the literature, the in-commuting and the net-commuting are expected to be influenced by the number of working places, urbanization degree and personal incomes. Further, high unemployment in neighbourhood municipalities should give rise to a higher in-commuting. For the out-commuting, determinant factors are expected to be unemployment, a large workforce population share and low availability of workplaces. Family structures are expected to influence the propensity to commute, as a low average number of inhabitants per household dampens this propensity. The causal relationship between commuting patterns and sociodemographic conditions will be investigated using the

well known linear regression formulation, i.e.

$$y = X\beta + \mu, \mu \sim N(0, \sigma^2 I)$$

where  $y$  is an  $n$ -vector of observations for one of the considered commuting variable ( $n$  being the number of municipalities, i.e.  $n = 275$ ),  $X$  an  $n$  by  $k$  matrix of  $n$  observations for  $k$  sociodemographic variables,  $\beta$  a  $k$ -vector of regression coefficients,  $\mu$  an  $n$ -vector of random errors, assumed to be independent of each other and identically normally distributed with mean value 0 and common variances  $\sigma^2$ , as  $I$  is an  $n$  by  $n$  identity matrix.

To this point, the causal relationship between sociodemographic characteristics - describing the workforce - and commuting patterns has been formulated much in accordance with known empirical findings. What has not been formulated is the spatial patterning of industries and the implications of this patterning for commuting behaviour. Actually, only a few relevant statements about industrial patterning has been provided: Some industries with preferences for low wages locate in low-wage areas, i.e. rural areas and small- and medium sized cities. Other industries with emphasize on infrastructure, knowledge and highly skilled employees prefer urban areas. From this, it is obvious that a spatial clustering of some industries should emerge and that commuting occurs due to the contradiction between this clustering and the spatial pattern in choice of livingplaces, as people necessarily have to follow the supplied jobs.

Due to the aforementioned lack of data for industrial localization on a municipality base, it is impossible to estimate a causal relationship between this determinant and commuting. Another route to recognize this relationship will be followed in this investigation, as illustrated by the following informal argumentation: Suppose that the in-commuting to a specific municipality is high. Then two conclusions may be drawn: First, there is a high concentration of industries attracting commuters in this municipality. Second, there may be a high concentration of these industries in neighbourhood municipalities, giving rise to a high in-commuting to these municipalities. Conversely, a high out-commuting from a specific municipality is caused by a lack of firms in certain industries, a lack which may also be found in neighbourhood municipalities whereby a high out-commuting is expected from these too.

These ideas may be formalized using a spatial autoregressive specification as suggested by Anselin (1988a). Define an  $n$  by  $n$  contiguity matrix  $W$  as

$$\begin{aligned} w_{ij} &= 1 \text{ if municipalities } i \text{ and } j \text{ are neighbours,} \\ w_{ij} &= 0 \text{ otherwise, and} \\ w_{ii} &= 0 \end{aligned}$$

and a spatial autoregressive process as

$$y = \rho W y + \mu, \mu \sim N(0, \sigma^2 I)$$

where  $\rho$  is an autoregression parameter between -1 and 1. For the present case,  $\rho$  is restricted to the interval between 0 and 1 in order to be meaningfully interpreted. Further,  $W$  is - according to common practice - rowstandardized, i.e. each element in the matrix is divided by the number of elements in the row to which it belongs. By this, the  $i$ 'th elements of the  $n$ -vector  $W y$  is simply the average of the  $y$  variable in the neighbours to the  $i$ 'th municipality.

A straightforward combination of the causal model and the autoregressive process gives the causal-autoregressive specification

$$y = \rho W y + X\beta + \mu, \mu \sim N(0, \sigma^2 I)$$

One complication about this specification is the suggested independence between the causal model and the autoregressive process. Actually, as the sociodemographic conditions used to specify the workforce are of a rather ad-hoc or proxy nature they may partly capture features which are due to the underlying spatial processes. Formally, one may expect the spatial Durbin process to be more adequate, specified as

$$y = \lambda W y + X\beta + \lambda W X \beta + \mu, \mu \sim N(0, \sigma^2 I).$$

In this specification, the autoregressive process is specified simultaneously outside the causal model by the term  $\lambda W y$  and inside the causal model by the spatial spill-over term  $\lambda W X \beta$ . Following Anselin (1988a) and the common practice in spatial econometric literature, the spatial Durbin process may be rewritten, using simple algebraic manipulations, as

$$\begin{aligned} y &= X\beta + \epsilon \\ \epsilon &= \lambda W \epsilon + \mu, \mu \sim N(0, \sigma^2 I), \end{aligned}$$

i.e. the spatial autocorrelated error model. Finally, the spatial Durbin specification may be combined with the autoregressive process, reading as

$$\begin{aligned} y &= \rho W y + X\beta + \epsilon \\ \epsilon &= \lambda W \epsilon + \mu, \mu \sim N(0, \sigma^2 I), \end{aligned}$$

whereby the spatial dependence is specified as a model specific part (the spatial Durbin process) and a model independent part (the autoregressive process).

The spatial autoregressive, the spatial Durbin and the combined models may be estimated using asymptotically justified maximum likelihood estimation as described in Anselin (1988a). However, these estimations is not without problems. First, it is quite computer-demanding and the methods are not implemented in commonly used packages. Second, methodological problems arise pertaining to the asymptotic justification of the estimated models, which especially renders traditionally used model selection criteria invalid. Consequently, in order to evaluate the relative impacts of different spatial specifications and to support model selection, a Lagrange Multiplier pre-test strategy is applied. Specifically, this strategy consists of an estimation of the simple linear causal model without any spatial processes, followed by a comparison with different alternative specifications using a Lagrange Multiplier test for each (see Anselin 1988a, 1988b for a detailed outline of the tests).

### 3. Empirical results.

Based on the availability of census data for the 275 Danish municipalities (see the map in Figure 1) three analysis variables were selected to describe commuting behaviour:

OUTCOM: Number of persons with residence in the municipality and workplace in another municipality in percentage of the number of workplaces in the municipality, 1994 (Source: Danish Statistical Bureau).

INCOM: Number of persons with residence in another municipality and workplace in the municipality in percentage of the number of workplaces in the municipality, 1994 (Source: Danish Statistical Bureau).

NETCOM: Calculated as INCOM - OUTCOM.

To capture the sociodemographic conditions describing workforce characteristics expected to impact commuting behaviour, the following variables were selected:

WORKPL: Number of workplaces per 100 inhabitants, 1994 (Source: Danish Statistical Bureau).

POPDEN: Population density - inhabitants per square kilometre, 1994 (Source: Danish Statistical Bureau).

TAXBAS: Taxable incomes per inhabitant, 1994 (Source: Local Authority Key Data, the Ministry of the Interior).

PSH1766: Population share of 17-66 year-olds, 1994 (Source: Danish Statistical Bureau).

IPHOUS: Inhabitants per household, 1994 (Source: Danish Statistical Bureau).

UNEMP: Unemployed per 100 17-66 year-olds, 1994 (Source: Danish Statistical Bureau).

UNEMP1: Average of UNEMP in neighbourhood municipalities.

For out-commuting, the causal model is specified as

$$\text{OUTCOM} = f_1(\text{PSH1766}, \text{WORKPL}, \text{IPHOUS}, \text{UNEMP}).$$

The population share of 17-66 year-olds - i.e. the share of population in economically active age - is expected to have a positive impact on out-commuting. Likewise, the number of inhabitants per household is expected to have a positive impact as the propensity to commute is expected to be higher for two-parent families than for single-parent families. A high number of workplaces is clearly expected to reduce the commuting propensity. Unemployment may be expected to have a positive impact, but a negative impact may be found as well due to geographic and professional immobility of the unemployed.

For in-commuting, the causal model reads as

$$\text{INCOM} = f_2(\text{WORKPL}, \text{POPDEN}, \text{TAXBAS}, \text{UNEMP1}),$$

where all four variables are expected to have positive impacts.

The same specification is suggested for net-commuting:

$$\text{NETCOM} = f_3(\text{WORKPL}, \text{POPDEN}, \text{TAXBAS}, \text{UNEMP1}),$$

with positive impacts expected for all four variables.

Estimating these three specifications using the well known Ordinary Least Squares linear regression method and omitting variables which did not meet the significance level of 10 percent, the results in Table 1 were derived.

(Table 1)

For the OUTCOM specification, the coefficients for PSH1766, IPHOUS and WORKPL behaves as expected. The coefficient for UNEMP is found to be negative, indicating that municipalities with high unemployment have structural problems related to geographical and professional immobility of the workforce. The LM-L test for an omitted spatial autoregressive structure as well as the LM-E test for a spatial Durbin proces and the LM-EL test for a combined process strongly indicates the presence of local spatial patterns. Especially, the high LM-E value indicates a strong spatial clustering pattern in the fit of modelled behaviour to actual behaviour. Combined with the high LM-L value, the presence of local industrial clustering is an evident cause to commuting.

For the INCOM specification, the coefficients for WORKPL, POPDEN and TAXBAS behave as expected. However, it is not possible to trace a significant impact from unemployment in neighbourhood municipalities, UNEMP1. The high values of all three LM tests for spatial patterns strongly indicates the importance of local industrial clustering as a factor attracting commuters.

For the NETCOM specification, the coefficients for UNEMP1 and WORKPL were as expected, whereas no significant impact were found from POPDEN and TAXBAS. A straightforward interpretation of these findings is that in-commuting and the (surplus) net-commuting are conceptually different: It is clear that people commute to urban areas where high incomes may be earned. But this in-commuting is to an important degree outweighed by out-commuting of people who are not able to fit into these jobs. Consequently, the impact of urbanisation degree and income levels are washed out when fitted to net-commuting. The LM tests for the NETCOM specification are very high, indicating a strong presence of local industrial patterns attracting commuters.

Combining the spatial autoregressive process with the causal model, the results in Table 2 were estimated.

(Table 2)

A combination of the spatial Durbin process and the causal gave the estimates in Table 3.

(Table 3)

Finally, a causal model combined with a spatial Durbin and an autoregressive specification were estimated. However, as the coefficient for the autoregressive terms were found to be strongly insignificant in all three models, these results are not found interesting and therefore not reported.

From the results reported in Tables 2 and 3, the presence of spatial dependencies is evident. The significant presence of spatial autoregressive structures (Table 2) strongly indicate impact from local industrial clustering on commuting behaviour. The highly significant and statistically stronger presence of spatial Durbin processes indicate that this impact is partly measured by the sociodemographic variables due to the proxy nature of these determinants.

Some conclusions about the relative importances of the causal model and the spatial processes may be drawn. Comparison of the results in Tables 2 and 3 with the results from Table 1 shows that the impact of several sociodemographic variables are misestimated when ignoring spatial dependencies. For the impact on out-commuting, the workforce size coefficient is overestimated in the simple specification, whereas the impact of inhabitants per household is strengthened when the spatial Durbin process is accounted for. Regarding the in-commuting, a higher coefficient is estimated for the number of workplaces in the spatial Durbin version, whereas the impact of urbanization and personal incomes are adjusted downward. Finally, for the net-commuting specification the impact of unemployment in neighbourhood municipalities is lower when adjusting for a spatial Durbin process, whereas the impact of number of workplaces is stable.

#### **4. Conclusions.**

Following suggestions from recent literature, the present paper has estimated causal relationship between socio-demographic workforce characteristics and commuting behaviour. These causal models are generalized to capture the influence of unmeasured industrial clustering patterns, using spatial Durbin- and spatial autoregressive specifications. Finally, it is shown that the magnitudes of the impacts on commuting behaviour are seriously misestimated for several sociodemographic criteria when the presence of these spatial patterns is ignored.

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## Tables and figures.

	OUTCOM	INCOM	NETCOM
CONSTANT	-264.62 (-7.88)	-24.41 (-6.10)	-182.63 (-23.39)
PSH1766	6.29 (17.49)		
WORKPL	-2.33 (-22.99)	0.255 (5.17)	2.82 (30.19)
IPHOUS	18.78 (2.33)		
UNEMP	-3.39 (-6.46)		
UNEMP1		?	3.89 (6.32)
POPDEN		0.0042 (5.23)	?
TAXBAS		0.0005 (12.42)	?
R <sup>2</sup>	0.81	0.57	0.77
R <sup>2</sup> (adj.)	0.80	0.57	0.77
F	283.6	120.9	455.8
prob(F)	0.0001	0.0001	0.0001
LM-E	48.49	57.77	35.45
prob(.)	<0.0001	<0.0001	<0.0001
LM-L	4.15	99.25	11.37
prob(.)	0.042	<0.0001	0.0007
LM-EL	53.28	100.27	35.45
prob(.)	<0.0001	<0.0001	<0.0001

Table 1. Causal models for commuting.

Numbers in parentheses are t-values.

Question marks indicate absence of variables expected to be significant.

	OUTCOM	INCOM	NETCOM
CONSTANT	-233.62 (-6.51)	-20.01 (-6.39)	-176.53 (-22.56)
$\rho$	0.11 (2.31)	0.60 (13.17)	0.15 (3.34)
PSH1766	5.67 (13.32)		
WORKPL	-2.31 (-23.02)	0.32 (8.19)	2.80 (30.51)
IPHOUS	19.94 (2.50)		
UNEMP	-3.39 (-6.58)		
UNEMP1			3.72 (5.32)
POPDEN		0.0017 (2.59)	
TAXBAS		0.0002 (5.83)	
$R^2$	0.82	0.61	0.78
Log L	-1159.53	-947.94	-1171.16

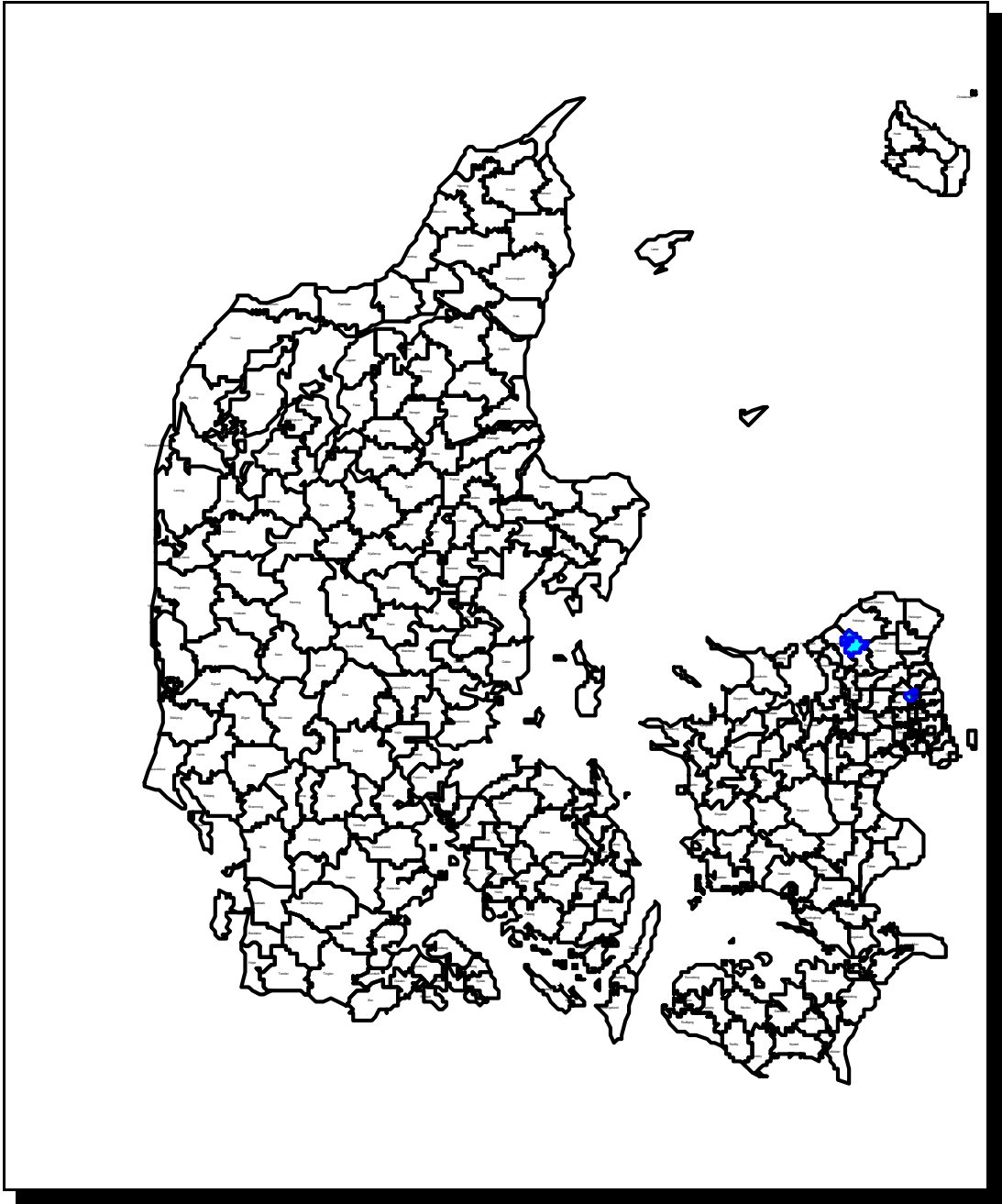
Table 2. Combined causal/spatial autoregressive models for commuting.

Numbers in parentheses are asymptotic t-values.

$R^2$  is the squared correlation between  $y$  and  $X\beta$ .

	OUTCOM	INCOM	NETCOM
CONSTANT	-245.15 (-6.86)	-0.07 (-0.01)	-172.54 (-18.06)
$\lambda$	0.63 (6.86)	0.71 (15.33)	0.44 (6.34)
PSH1766	4.72 (10.97)		
WORKPL	-2.23 (-25.57)	0.31 (8.21)	2.81 (33.19)
IPHOUS	52.70 (6.77)		
UNEMP	-3.58 (-6.15)		
UNEMP1			2.87 (3.35)
POPDEN		0.0021 (2.15)	
TAXBAS		0.0002 (4.05)	
$R^2$	0.83	0.19	0.77
Log L	-1126.9	-961.8	-1160.1

Table 3. Combined causal/spatial Durbin models for commuting.  
Numbers in parentheses are asymptotic t-values.  
 $R^2$  is the squared correlation between  $y$  and  $X\beta$ .



**Figure 1.** The Danish municipality structure.