Gråsjö, Urban; Arvemo, Tobias

Conference Paper

Different measures of economic growth lead to different conclusions?

50th Congress of the European Regional Science Association: "Sustainable Regional Growth and Development in the Creative Knowledge Economy", 19-23 August 2010, Jönköping, Sweden

Provided in Cooperation with:

European Regional Science Association (ERSA)

Suggested Citation: Gråsjö, Urban; Arvemo, Tobias (2010) : Different measures of economic growth lead to different conclusions?, 50th Congress of the European Regional Science Association: "Sustainable Regional Growth and Development in the Creative Knowledge Economy", 19-23 August 2010, Jönköping, Sweden, European Regional Science Association (ERSA), Louvain-la-Neuve

This Version is available at:
https://hdl.handle.net/10419/119268

Preliminary draft:

Different measures of economic growth lead to different conclusions?

Tobias Arvemo[1] & Urban Gråsjö[2]

Abstract

When regional growth studies are conducted, a common measure of economic growth is the wage sum. One reason for this may be the limited access to GDP (Gross Domestic Product) data on regional level. However, in Sweden there exists GDP data on municipal level, which enables studies where the effects of using GDP data or wage data can be compared.

The aim of the present study is to investigate the difference the use of the measures GMP (Gross Municipal Growth) and the sum of wages has on growth models. Since the two measures are similar but not identical the choice of measure of growth can influence the conclusions of an investigation. This might lead to contradictory results on for instance how the accessibilty to university research influences the economic growth (Andersson, Gråsjö & Karlsson 2007, 2008). Preliminary results indicate high positive correlations between changes in GMP and wage sum on municipal level. However, when data on GMP per capita and wage sum per capita are used, the correlations are still positive but much smaller.

[1] Tobias.arvemo@hv.se, University West, Sweden

[2] Corresponding author, Urban.grasjo@hv.se, University West, Sweden

1. Introduction

Growth and regional growth are nowadays constantly concepts of current interest. Studies of regional growth have been conducted by numerous scholars but the way that the growth concept is defined and the way it is measured varies a lot. Lack of proper regional data may be a reason why this discrepancy occurs. A more cynical view is that the possibility to chose different variants that fits own purposes is large and very tempting.

Value added and wage sum are two frequently used measures in studies of production, productivity and economic growth. The present study focuses on the question to what extent the use of different measures affect the assessments of production, growth and productivity on municipal level. The paper is organized as follows: In the next section the concept of economic growth and regional economic growth is discussed. Different measures of production growth and productivity on regional level are also presented. In section 3, descriptive comparisons of GMP and wage sum in different contexts are conducted. Section 4 contains empirical tests on whether it matters to use GMP or wage sum on municipal level when forming an output variable to be used in regression models of economic growth. Section 5 concludes.

- *To be completed* -

2. Regional economic growth

2.1 The concept of economic growth

In strict basic economic theory there is a distinction between growth and increased production. Growth is about how the production possibility increases over time. The production possibility can increase due to a productivity increase and/or an increased supply of production factors. These are structural changes in the economy which in turn increase production. On the other hand, when production varies due to seasonal and/or cyclical changes the production possibility in a country is still the same. However, the word growth is usually used to denote production increase. This is the case not only in the public debate but also among scholars doing growth studies. It is also impossible to find data of "true" economic growth according to the strict definition. Generally data of changes in Gross Domestic Product (or similar concepts) is used to measure economic growth on country level. In order to measure growth for regions value added on regional level is used, such as Gross Regional Product (GRP) for regions. Besides the usual objections of using GDP as a measure of nation's welfare, there are additional doubts of using GRP as a measure of a region's well being. In a country (like Sweden), all resources are treated as common. The goods and services produced with the use of these resources are then divided among individuals in different regions. Therefore it is not certain that a region with strong regional economic growth automatically has a higher economic welfare than regions with lower economic growth.

2.2 Measures of regional economic growth

There are different ways to measure economic growth on regional level. In Sweden the GRP change is for instance used by Statistics Sweden and Swedish Agency for Economic and Regional Growth.[3]

The Swedish Agency for Growth Policy Analysis (Growth Analysis) on the other hand uses changes in labour productivity as a measure of economic growth in regions[4]. Growth Analysis then use wage sum per employed or wage sum per inhabitant as an estimator for labour productivity.

Gross Regional Product (GRP) is a summation of value added of all produced goods and services for all sectors in a region. In order to measure economic growth in a region (ΔY) the following formula is used:

$$\Delta Y = \frac{GRP_t - GRP_{t-1}}{GRP_{t-1}}$$

[3] Swedish Agency for Economic and Regional Growth operations include the areas of responsibility previously belonging Nutek and the Swedish National Rural Development Agency as well as the Swedish Consumer Agency's tasks concerning commercial and public service.

[4] The Swedish Agency for Growth Policy Analysis (Growth Analysis) is charged by the Government to shed light on the areas most significant to growth. The Agency's overriding objective is to strengthen Swedish competitiveness and create the conditions for more jobs in more and growing companies throughout the country.

Wage sum is an important component in GRP because GRP can be calculated by a summation of wage sum and enterprises' operating surplus. Wage sum (w) changes are therefore sometimes used as an indicator of regional economic growth according to the formula:

$$\Delta Y = \frac{w_t - w_{t-1}}{w_{t-1}}$$

If the wage sum can be allocated to the region where the individuals actually work it should covariate with GRP. This allocation is problematic since many firms have activities in several regions.

GRP per employed is an approximation of the labour productivity in a region. Of course production in some industries is more labour intensive than in others. This will affect the productivity value and therefore it is difficult to compare regions' productivity levels. Changes in GRP per employed must also be interpreted with care, since increased unemployment in a region might affect GRP negatively and GRP per employed positively. The region then experiences reduced economic growth and an increased labour productivity.

- *To be completed* -

3. A descriptive analysis of GMP and wage sum

- GMP vs. wage sum
- GMP per employee (and per capita) vs. wage sum per employee (and per capita)
- GMP change vs. wage sum change (absolute and in percent)
- GMP per employee change vs. wage sum per employee change (absolute and in percent)

Table 1: Correlations between GMP and wage sum, 1993-2006.

Year	GMP vs Wage sum	ΔYear	Absolute change	Change in %
1993	0.998			
1994	0.998	94-93	0.773	0.267
1995	0.998	95-94	0.783	0.982
1996	0.998	96-95	0.949	0.192
1997	0.999	97-96	0.900	0.117
1998	0.999	98-97	0.944	0.205
1999	0.999	99-98	0.946	0.224
2000	0.999	00-99	0.853	0.185
2001	0.999	01-00	0.620	0.185
2002	0.999	02-01	0.229	0.221
2003	0.999	03-02	0.739	0.206
2004	0.998	04-03	0.683	0.186
2005	0.998	05-04	0.942	0.263
2006	0.998	06-05	0.882	0.266

Table 2: Correlations between GMP per inhabitant and wage sum per inhabitant, 1993-2006.

Year	GMP vs wage sum	ΔYear	Absolute change	Change in %
1993	0.823			
1994	0.843	94-93	0.304	0.296
1995	0.824	95-94	0.328	0.293
1996	0.868	96-95	0.136	0.137
1997	0.914	97-96	0.055	0.080
1998	0.941	98-97	0.187	0.181
1999	0.936	99-98	0.481	0.223
2000	0.923	00-99	0.280	0.163
2001	0.862	01-00	0.216	0.195
2002	0.871	02-01	0.255	0.197
2003	0.874	03-02	0.389	0.204
2004	0.874	04-03	0.296	0.195
2005	0.840	05-04	0.271	0.277
2006	0.872	06-05	0.400	0.244

Table 3: Correlations between GMP per employee and wage sum per employee, 1993-2006.

Year	GMP vs wage sum		Absolute change	Change in %
1993	0.456			
1994	0.525	94-93	0.486	0.548
1995	0.519	95-94	0.465	0.508
1996	0.503	96-95	0.436	0.579
1997	0.626	97-96	0.378	0.367
1998	0.674	98-97	0.459	0.526
1999	0.665	99-98	0626	0.654
2000	0.650	00-99	0.635	0.641
2001	0.445	01-00	0.398	0.499
2002	0.459	02-01	0.474	0.503
2003	0.457	03-02	0.627	0.652
2004	0.527	04-03	0.634	0.635
2005	0.482	05-04	0.562	0.631
2006	0.564	06-05	0.634	0.635

- *To be completed* -

4. An empirical test on regional economic growth

In this paper, the empirical analysis is partly based on a spatial cross-regressive model (c.f. Rey & Montouri 1999) with accessibility variables (to R&D) on the right-hand-side. In such a model, the extent of spatial dependence is revealed by the magnitude and significance of the estimated parameters associated with the accessibility variables (Andersson & Gråsjö 2006). The method with accessibilities in knowledge production has been used in a series of papers, (see e.g. Gråsjö, 2006; Andersson & Ejermo, 2004a,b; Andersson & Karlsson, 2007).

The accessibility measure used here belongs to the family of such measures that satisfy criteria of consistency and meaningfulness (Weibull 1976, 1980). The accessibility of location *i* to itself and to *n-1* surrounding locations is defined as the sum of its internal accessibility to a given opportunity *X* and its accessibility to the same opportunity in other locations (not only neighbours),

$$A_i^X = x_1 f(c_{i1}) + \ldots + x_i f(c_{ii}) + \ldots + x_n f(c_{in}) \qquad (1)$$

where A_i^X is the total accessibility of location *i* and x_i is a measure of an opportunity *X*.[5] *f(c)* is the distance decay function that determines how the accessibility value is related to the cost of reaching the opportunity. A very common way of calculating an accessibility value when the accessibility is interpreted as potential of opportunity, is to use an exponential distance-decay function (see e.g. Martellato, Nijkamp & Reggiani, 1998), and then *f(c)* takes the following form,

$$f(c_{ij}) = \exp\{-\omega t_{ij}\} \qquad (2)$$

where t_{ij} is the time distance between location *i* and *j,* and ω is a time sensitivity parameter. The value of ω in (3.3) depends on if the interaction is local, intra-regional (between locations in a region), or inter-regional (location *i* and *j* in different regions). It is apparent that the accessibility value may improve in two ways, either by an increase in the size of the opportunity, x_j, or by a reduction in the time distance between location *i* and *j*. If the total accessibility to a specific opportunity is decomposed into local, intra-regional and inter-regional, then

$$A_i^X = A_{iL}^X + A_{iR}^X + A_{iOR}^X \qquad (3)$$

where

$A_{iL}^X = x_i \exp\{-\omega_L t_{ii}\}$, local accessibility to opportunity *X* for location *i*
$A_{iR}^X = \sum_{r \in R,\ r \neq i} x_r \exp\{-\omega_R t_{ir}\}$, intra-regional accessibility to opportunity *X* for location *i*
$A_{iOR}^X = \sum_{k \notin R} x_k \exp\{-\omega_{XR} t_{ik}\}$, inter-regional accessibility to opportunity *X* for location *i*

j defines locations within the own region *R*, and *k* defines locations in other regions.

[5] In this paper, the municipalities in Sweden are the locations and conducted R&D is the opportunity.

The accessibility concept has several advantages. Firstly, it incorporates "global" spillovers and does not only account for the impact from neighbours or locations within a certain distance band. Secondly, the separation of the total effect into local, intra-regional and inter-regional spillovers captures potential productive knowledge flows between locations and makes the inferential aspects more clear. Thirdly, distance is often measured by the physical distance, but a better way to measure it is to use the time it takes to travel between different locations (Beckman, 2000). Time distances are also crucial when it comes to attending business meetings and also to spatial borders of labour markets (see Johansson & Klaesson, 2001, for the Swedish case). Thus, accessibility provides a connection between the functional and the spatial component of an urban system (Bertuglia & Occelli, 2000). It defines the range and temporal organization of economic opportunities available in space as well the cost of overcoming space in order to explore the opportunities in different locations. Accessibility accounts for the size of an opportunity in a location and discounts the value of the opportunity with time distance in a way that reflects the willingness to explore that opportunity given its size and distance. Accessibility is also a robust operational measurement tool which makes spatial proximity operational (Karlsson & Manduchi, 2001)

In the accessibility calculations the time sensitivity parameter value ω_L is set to 0.02, ω_R to 0.1 and ω_{XR} to 0.05. Johansson, Klaesson & Olsson (2003) estimated these values by using data on commuting flows within and between Swedish municipalities in 1990 and 1998. It may look strange that the intra-regional accessibilities have the highest parameter value (ω_R = 0.1). But the intra-regional commuting trips, which are in the time span from approximately 15 to 45 minutes, are the ones that are most time sensitive. That is, increased commuting time in this time span will hamper the propensity to travel the most. When the accessibility variables have been calculated they can be entered in the empirical model.

4.1 The empirical model

As stated in section 2, economic growth and productivity changes are usually measured by GRP or wage sum changes. The purpose of the empirical test is to examine whether or not the use of GMP and wage sum respectively in a regional economic growth model give rise to different results. In order to do a thorough comparison between GMP and wage sum on municipality level we are going to estimate the empirical model eight times, with eight different dependent variables. Local, intra-regional and inter-regional accessibility to R&D measured in man-years are the main explanatory variables. The model will also include indicator variables for whether or not the municipality has a large agricultural sector (more than 5% of the population employed within farming) and if the public sector is a dominant employer in the region (large share of public sector employment is defined as 35 % or higher). The analysis will also include an indicator variable for whether or not the municipality is the central municipality in the region and also if the municipality belongs to a large local labor market. Furthermore, the initial level of GMP per employee and wage sum per employee respectively are used on the right hand side in the model. This variable will give us the opportunity to determine if the municipalities' productivity converge or diverge. Hence the model is:

$$Y_i = a + b_1 A_{iL}^{R\&D} + b_2 A_{iR}^{R\&D} + b_3 A_{iXR}^{R\&D} + b_4 I_i^{AGR} + b_5 I_i^{PUB} + b_6 I_i^{CENT} + b_7 I^{LREG} + b_8 Z_i + \varepsilon_i \qquad (4)$$

where

Y_i is a proxy for economic growth in municipality *i* (see below)

$A_{iL}^{R\&D}$ is the local (intra-municipal) accessibility to company R&D in municipality i

$A_{iR}^{R\&D}$ is the intra-regional accessibility to company R&D in municipality i

$A_{iXR}^{R\&D}$ is the inter-regional accessibility to company R&D in municipality i

I_i^{AGR} is a dummy variable for large agriculture sector employment

I_i^{PUB} is a dummy variable for large public sector employment

I_i^{CENT} is a dummy variable for largest municipality in a functional region

I_i^{LREG} is a dummy variable for municipality in large functional region

Z_i is either GMP per employee 1993 or Wage sum per employee 1993 in municipality i

ε_i is assumed to be independent errors.

There is a discussion in the literature about the proper time lag between R&D investments and potential subsequent economic growth. We are testing two different time lags. The R&D variables in (4) are yearly averages between 1993 and 1998 and the dependent variable Y_i in (4) is defined as follows:

$$Y_i = \frac{GMP_{i,t} - GMP_{i,t-1}}{GMP_{i,t-1}}; Y_i = \frac{GMPpe_{i,t} - GMPpe_{i,t-1}}{GMPpe_{i,t-1}}; \; Y_i = \frac{W_{i,t} - W_{i,t-1}}{W_{i,t-1}}; \; Y_i = \frac{Wpe_{i,t} - Wpe_{i,t-1}}{Wpe_{i,t-1}}$$

where

GMP_i is Gross municipal product in municipality i, W_i is wage sum in municipality i, pe stands for per employee, t is 2001 and 2006, respectively, and $t-1$ is 1993.

If there is no evidence of collinearity the estimation will be done with Ordinary Least Squares (OLS). The hypothesis is that the reach of influential knowledge flows is bounded geographically. This means that the parameter estimates of the local and/or intra-regional accessibilities to R&D are supposed to be positive and statistically significant.

4.2 Data and descriptive statistics

Descriptive statistics of the data used for the variables in the regressions are presented in Table 4 and 5. The data consists of all municipalities (n = 286) in Sweden during.[6] The data includes the accessibility to R&D on three spatial levels: local, intra-regional and inter-regional. R&D is measured in man-years and calculated as yearly averages during the period of 1993 to 1999. Data of the commuting time between and within municipalities in 1990 and 1998 is used for calculating the accessibility variables. GMP and wage sum are calculated as percentage changes from 1993 to 2001 and from 1993 to 2006. The same goes for GMP per employee and wage sum per employee.

[6] Statistics Sweden is the data source of all data, accept on commuting time. National Road Administration in Sweden is the data source when it comes to commuting time between and within Swedish municipalities.

Table 4: Descriptive statistics for continuous variables

	Mean	Median	Std. Dev	Min	Max
Local acc R&D	172.775	6.572	926.2489	0.000	12348.23
Intra-reg acc R&D	391.811	17.337	1027.3998	0.000	7493.83
Inter-reg acc R&D	280.942	170.326	335.1028	0.002	1955.90
GMP(01-93)/93	0.391	0.366	0.2107	-0.11	1.25
GMP(06-93)/93	0.682	0.677	0.2980	0.01	1.80
GMPpe(01-93)/93	0.355	0.336	0.1821	-0.19	0.94
GMPpe(06-93)/93	0.657	0.650	0.2489	0.01	2.18
W(01-93)/93	0.422	0.430	0.1747	-0.21	1.20
W(06-93)/93	0.667	0.671	0.2447	0.03	1.75
Wpe(01-93)/93	0.382	0.376	0.1112	-0.03	0.82
Wpe(06-93)/93	0.639	0.630	0.1476	0.27	1.74

Indicator variables (see Table 5) were calculated for, whether the municipalities are considered agricultural areas, if the public sector where a large employer, if the municipality was the economic centre of the region, if the municipality belonged to a large population region.

Table 5: Descriptive statistics for dummy variables

		Share
Central municipality in local labor market	No	71,7%
	Yes	28,3%
Municipality in large local labor market	No	51,0%
	Yes	49,0%
Municipality with large agricultural sector	No	68,2%
	Yes	31,8%
Municipality with large public sector	No	55,9%
	Yes	44,1%

4.3 Results

Table 6: Marginal effects on the percentage change of GMP and wage sum, 1993 – 2001.

Change in GMP between 1993 and 2001 in %			Change in Wage sum between 1993 and 2001 in %		
	Coef.	**t**		**Coef.**	**t**
Local acc R&D	0.000033	**2.67**	*Local acc R&D*	0.000035	**3.54**
Intra-reg acc R&D	0.000065	**5.42**	*Intra-reg acc R&D*	0.000061	**6.32**
Inter-reg acc R&D	0.000034	1.00	*Inter-reg acc R&D*	0.000063	**2.29**
Central mun	0.004511	0.14	*Central mun*	-0.041525	-1.58
Large reg	0.008539	0.28	*Large reg*	-0.005745	-0.24
Agric	-0.033017	-1.32	*Agric*	-0.050584	**-2.36**
Public	-0.063975	**-2.83**	*Public*	-0.062250	**-3.44**
GMP per emp 93	-0.000578	**-4.84**	*Wage sum per emp 93*	-0.002543	**-4.13**
constant	0.607576	10.74	*constant*	0.821230	8.24
R^2	0.2342			0.2838	

Table 7: Marginal effects on the percentage change of GMP and wage sum, 1993 – 2006.

Change in GMP between 1993 and 2006 in %			Change in Wage sum between 1993 and 2006 in %		
	Coef.	**t**		**Coef.**	**t**
Local acc R&D	0.000047	**2.80**	*Local acc R&D*	0.000052	**3.64**
Intra-reg acc R&D	0.000099	**6.03**	*Intra-reg acc R&D*	0.000080	**5.83**
Inter-reg acc R&D	0.000044	0.93	*Inter-reg acc R&D*	0.000063	1.64
Central mun	0.042383	0.95	*Central mun*	-0.019542	-0.53
Large reg	0.037535	0.91	*Large reg*	0.010581	0.31
Agric	-0.096808	**-2.83**	*Agric*	-0.071920	**-2.37**
Public	-0.037810	-1.23	*Public*	-0.055985	**-2.19**
GMP per emp 93	-0.000874	**-5.36**	*Wage sum per emp 93*	-0.005371	**-6.17**
constant	0.978265	12.69	*constant*	1.477557	10.47
R^2	0.2880			0.2685	

Table 8: Marginal effects on the percentage change of GMP and wage sum per employee, 1993 – 2001.

Change in GMP per employee between 1993 and 2001 in %			Change in Wage sum per employee between 1993 and 2001 in %		
	Coef.	**t**		**Coef.**	**t**
Local acc R&D	0.000015	1.34	*Local acc R&D*	0.000018	**2.74**
Intra-reg acc R&D	0.000022	**2.06**	*Intra-reg acc R&D*	0.000019	**2.90**
Inter-reg acc R&D	-0.000022	-0.71	*Inter-reg acc R&D*	0.000016	0.89
Central mun	0.045430	1.57	*Central mun*	0.000614	0.04
Large reg	0.020572	0.77	*Large reg*	0.002659	0.17
Agric	0.024628	1.10	*Agric*	0.003700	0.26
Public	-0.048548	**-2.41**	*Public*	-0.043984	**-3.71**
GMP per emp 93	-0.000770	**-7.24**	*Wage sum per emp 93*	-0.002983	**-7.39**
constant	0.638658	12.69	*constant*	0.840038	12.84
R^2	0.1875			0.2379	

Table 10: Marginal effects on the percentage change of GMP and wage sum per employee, 1993 – 2006.

Change in GMP per employee between 1993 and 2006 in %			Change in Wage sum per employee between 1993 and 2006 in %		
	Coef.	**t**		**Coef.**	**t**
Local acc R&D	0.000018	1.19	*Local acc R&D*	0.000021	**2.38**
Intra-reg acc R&D	0.000024	1.66	*Intra-reg acc R&D*	6.17e-06	0.71
Inter-reg acc R&D	4.64e-08	0.00	*Inter-reg acc R&D*	0.000024	0.99
Central mun	-0.007344	-0.18	*Central mun*	-0.062681	**-2.66**
Large reg	-0.050360	-1.36	*Large reg*	-0.078295	**-3.61**
Agric	-0.050011	-1.62	*Agric*	0.010918	0.57
Public	-0.029371	-1.05	*Public*	-0.039550	**-2.44**
GMP per emp 93	-0.000997	**-6.77**	*Wage sum per emp 93*	-0.003075	**-5.57**
constant	1.085921	15.57	*constant*	1.166266	13.03
R^2	0.1652			0.1900	

- *To be completed* -

5. Conclusions

- *To be completed* -

References

Andersson, M. & Ejermo O., (2004a), How does Accessibility to Knowledge Sources affect the Innovativeness of Corporations? - Evidence from Sweden, *Annals of Regional Science*, 39(4), 741-765

Andersson, M. & Ejermo O., (2004b), Sectoral Knowledge Production in Swedish Regions 1993-1999", in Karlsson, C., Flensburg, P. & Hörte, S-Å (eds) (2004), *Knowledge Spillovers and Knowlegde Management*, Edward Elgar, Cheltenham: pp 143-170

Andersson, M & Gråsjö U., (2009), Spatial dependence and the representation of space in empirical models, *Annals of Regional Science* vol. 43, issue 1, pp. 159-180.

Andersson M., Gråsjö U. & Karlsson C. (2007), Regional Growth and Accessibility to Knowledge Resources: A Study of Swedish Municipalities, *The ICFAI Journal of Knowledge Management*, July 07

Andersson M., Gråsjö U. & Karlsson C., (2008), Human Capital and Productivity in a Spatial Economic System, *Annals of Economics and Statistics*, No 87/88 - 2008.

Andersson, M, & Karlsson, C., (2007), Knowledge in Regional Economic Growth – the role of knowledge accessibility, *Industry and Innovation*, 14(2), 129-149

Beckmann, M., (2000), Interurban Knowledge Networks. In Batten, D., Bertuglia, C.,

Gråsjö, U. (2006), Spatial Spillovers of Knowledge Production, JIBS Dissertation Series No. 034, Jönköping International Business School

Johansson, B. & Klaesson, J., (2001), Förhandsanalys av Förändringar i Transport- och Bebyggelsesystem, JIBS

Johansson, B., Klaesson, J., & Olsson M. (2003), Commuters' Non-Linear Response to Time Distances, *Journal of Geographical Systems*

Karlsson, C. & Manduchi, A., (2001), Knowledge Spillovers in a Spatial Context – A Critical Review and Assessment, in Fischer and Fröhlich (2001) (Eds.), *Knowledge, Complexity and Innovation Systems*, Springer-Verlag, Berlin

Martellato, D., Nijkamp, P & Reggiani, A., (1998), Measurement and Measures of Network Accessibility: economic perspectives, in Button, K, Nijkamp, P. & Priemus, H (eds), *Transport Networks in Europe; Concepts, Analysis and Policies*, Edward Elgar, pp 161-180

Rey, S & B Montouri (1999), US regional income convergence – a spatial econometric perspective, *Regional Studies*, 33, 143-156

Weibull, J., (1976), An Axiomatic Approach to the Measurement of Accessibility, *Regional Science and Urban Economics*, 6, 357-379

Weibull, J., (1980), On the Numerical Measurement of Accessibility, *Environment and Planning A*, 12: 53-67