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Urban structure as determinant of short distance goods transport

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Abstract

In this study, data on short distance goods transports is analysed in order to determine if variations in the amounts of goods generated could be explained by geographical and demographical variables. The main purpose is to see if the urbanization and concentration of economic activities has resulted in higher efficiency in the production process, thereby severing the link between increased economic activity and increased transport volumes. The study uses yearly data on freight transport made by truck in 21 Swedish counties between 2000 and 2009, making the number of observations 210. The final model estimated show that after taking geographical and demographical factors into account there is a negative relationship between economic activity and volume of goods transported. This indicates that it is possible to achieve economic growth without necessarily having to accept higher levels of goods transported locally.

Keywords: Freight; demand; generation; short-distance transport; economic growth

1. Introduction

For the last few decades, the transport sector is the only sector that has shown an appreciable increase in total CO_2 emissions in developed countries, as well as in the rest of the world. Besides contributing to global warming, increased transport volumes have also led to numerous other environmental problems including congestion. During last century total fossil carbon emissions increased fifteen times. In, for example, the USA the transport sector is responsible for around 25% of the CO_2 emissions while the same

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figure for Sweden is 30%. Globally, transport sector emissions are in this range. (US Department of Commerce, 2010; SOU, 2008)

For a long time, increased transport volumes have gone hand in hand with increasing economic activity and in the interest of sustainability, it would be most valuable if this link could be broken, i.e. economic growth could be achieved without being accompanied by increased traffic. Besides the record high rate of economic growth last century in the now rich countries, another long-term developments of great importance for the issue at stake has been, the far-reaching structural change of the economy, which in turn is interdependent with the urbanization. The change in spatial structural is a key factor for the long-term development of fossil fuel demand and climate policy.

According to UN population statistics, half the population of the world now lives in urban areas. This concentration is of importance for energy use in all sectors of the economy. However, cities produce surprisingly low carbon emissions per capita and that well designed and well governed cities can combine high living standards with lower greenhouse gas emissions. The greenhouse gas emissions of Barcelona residents are half the average for Spain, and Londoners have little more than half the UK average. Sao Paulo and Rio de Janeiro, the two largest cities in Brazil, have less than a third of the national average. Hence, wealth is not an inevitable emission driver. Tokyo has considerably lower greenhouse gas emissions per capita than either Beijing or Shanghai. (Dodman, 2009) The point is that the ubiquitous urbanization can be an important part of the solution if it takes a sustainable form.

The cities mentioned above are indeed great cities where coordination and transport planning, in addition to, a service-sector dominance over traditional manufacturing, has contributed to high efficiency in terms of emissions per dollar worth of production. However, it is possible that such gains in efficiency, or more, could be achieved under other forms of urban structure (e.g. many smaller cities instead of one large) as well. Since it is possible that the high efficiency seen in the large cities stems from other sectors than the transport sector it is also of interest to see if the link between production levels and transport volumes is in fact severed.

The purpose of this paper is therefore to estimate the effects of urban structure and economic activity on short distance freight transport. In doing so, this paper could provide valuable insights that can be used in order to form policy and incentives, aiming at breaking the link between economic growth and increased emissions from the transport sector.

The next section will present and discuss the data used in the study, as well as the context in which it originates.

2. Description of data

In order to fulfill the purpose, data on freight transport made by truck in 21 Swedish counties as well as key statistics describing demographics, geography and economic activity in those counties will be used. The study will use yearly data from the period 2000-2009, the number of observations are therefore 210. Data on fright volumes is obtained from the Swedish Agency for Transport Analysis who, among other things, is responsible for the official Swedish statistics concerning the transport sector. The data on other variables is obtained from Statistics Sweden (SCB).

Table 1 show the average amount of goods (thousands of tonnes) loaded in each county with destination within the same county between 2000 and 2009. This measure of short distance freight transports (which could be interesting in itself) is thought to serve as a proxy for within city transportation. By focusing on short distance freight it will be possible to answer the question of whether the link between economic growth and increased transport volumes is in fact severed. The table also show how large proportion of the total amount of goods loaded that consisted of within county transportation, Gross Regional Product (GRP) and the proportion of GRP that originates from the service sector.

The highest amounts of freight volumes can be seen in Västra Götaland, Skåne and Stockholm which also contain the three largest cities in Sweden, i.e. Stockholm, Gothenburg and Malmö. (See Fig. 1 for a map of Sweden and the Swedish counties) As can be seen, these counties also exhibit the highest level of economic activity (in terms of GRP) but also have the highest proportion of their production generated in the service sector. Gotland exhibits the highest proportion of within area transportation (95.7%) which is not surprising since it is an island.

Table 1. Freight volumes loaded and unloaded within (thousands of tons) the same county and economic information

County	Fright volume	Proportion of loaded goods with destination in same County (%)	GRP/capita	Prop. of production from Service sector
Stockholm	26 400	80.4	441.5	0.75
Uppsala	5 544	61.3	286.6	0.51
Södermanland	4 918	60.4	255.2	0.44
Östergötland	10 119	68.6	272.3	0.52
Jönköping	9 644	57.2	292.4	0.45
Kronoberg	5 561	51	296.7	0.51
Kalmar	7 836	71.5	273.4	0.44
Gotland	1 606	95.7	250.8	0.53
Blekinge	3 117	56.9	280.7	0.42
Skåne	30 359	76.3	286.8	0.58
Halland	7 535	65.7	270	0.52
Västra Götaland	39 193	76.2	315.3	0.58
Värmland	10 172	77.9	266.3	0.46
Örebro	6 158	54.9	277.8	0.47
Västmanland	4 713	46.6	270.7	0.44
Dalarna	9 234	67.3	289.7	0.41
Gävleborg	10 137	70.6	268.3	0.48
Västernorrland	14 121	84.4	301.2	0.47
Jämtland	5 514	69.3	275.4	0.51
Västerbotten	12 652	76.7	273.6	0.47
Norrbotten	12 187	91.9	303.3	0.38

Table 2 shows some key demographic statistics and it can be seen that the counties with the highest level of production as well as amount of goods transported, also have the highest population, in absolutes as well as in population density. It could be mentioned that the county of Stockholm generates far less transport volume per capita (14 tons per capita) than most of the other counties the second lowest being the neighboring county of Södermanland with 18 tons per capita. This could be compared to the counties of Västernorrland, Västerbotten and Norrbotten (located in the northern parts of Sweden) in which 63, 49 and 48 tons per capita were generated respectively.

The county of Stockholm has by far the highest proportion of built up areas (defined by statistics Sweden) with 10.78 percent while several counties consist of more than 99 percent rural areas. It is also apparent from Table 2 that Sweden is a sparsely populated country with a high level of urbanization.

Table 2. Country demographics

County	Population (Thousands)	Pop/Km2	Urbanization (%)	No. of Built up areas	Proportion of built up areas (%)
Stockholm	1 892	290	95.4	113	10.78
Uppsala	308	41	80.4	57	2.44
Södermanland	262	43	81.7	64,5	2.47
Östergötland	417	39	83.6	89	2.06
Jönköping	331	31	82.4	88	2.08
Kronoberg	179	21	76.3	52	1.49
Kalmar	234	21	77.2	93	1.62
Gotland	57	18	57.1	16,5	1
Blekinge	151	51	78.6	46,5	3.81
Skåne	1 169	106	87.6	245,5	5.25
Halland	284	52	78.5	95,5	3.48
Västra Götaland	1 526	64	83.2	309	3.36
Värmland	274	16	73.7	71	1.13
Örebro	275	32	82.1	62,5	2.36
Västmanland	257	44	85.9	46,5	2.93
Dalarna	277	10	79.2	107,5	1.09
Gävleborg	277	15	77.7	86,5	1.26
Västernorrland	244	11	75.8	77	0.92
Jämtland	128	3	65.4	54,6	0.19
Västerbotten	257	5	76.2	69,5	0.31
Norrbotten	253	3	81.8	92,5	0.25

3. A model for explaining short distance freight transport

In order to illustrate the original problem, i.e. the connection between economic activity and transport volumes, a basic model (1) explaining the amount of freight generated (measured in tkm) with economic activity (in terms of GRP) was estimated as a point of origin for the discussion. The model is:

$$Q1_{i,t} = \alpha_0 \cdot Y_{i,t}^{\alpha_1} \cdot e^{\varepsilon_{i,t}} \tag{1}$$

Where,
$Q1_{i,t}$ = Goods ($t$km) loaded in county i during period t
$Y_{i,t}$ = Gross Regional Product in county i during period t
$\varepsilon_{i,t}$ = Error term
$\alpha_0 - \alpha_1$ = Estimated Parameters

The results from OLS estimation of (1) is given in Table 3.

Table 3 Results from estimation of model (1), dependent variable is ln(Q1)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	-2.151042	0.698186	-3.080900	0.0023
Ln(Y)	0.733876	0.027706	26.48820	0.0000
R-squared	0.771334			
Adjusted R-squared	0.770235			

Since the model is transformed into linear form by the use of logarithms the estimated coefficient for Y can be interpreted as an elasticity, i.e. if GRP increase one percent in a county the transport volume generated in that county increase by 0.73 percent. This would indicate that the link between economic activity and transport volume is present and similar models are often used to illustrate this claim. It should be noted that the result is essentially the same (0.76) if goods loaded and unloaded within the same county is used as a dependent variable instead.

The question is whether this results remains if demographic and geographic factors are also taken into account. In order to investigate this, a model explaining the volume of short distance freight transport in relation to total production (gross regional product) in Swedish counties with urban structure, demographic factors and the level of economic activity is estimated. The models will be estimated using regression analysis (See e.g. Taniguchi *et. al.*, 2001) and take the general form of:

$$\frac{Q}{GRP} = \text{F (Urban Structure, Demographics, GRP)}$$

In this case Q is transport volume (tkm), loaded and unloaded within the same county. Since it is reasonable to assume that majority of such transports take place within a specific town, Q can therefore be seen as a proxy for urban transports.

Transport services can be seen as an input in the production process of the firms that complements other inputs, one can therefore expect transport volumes to be increasing in GRP and in order to capture how transport intensive the production process is and be able to relate that to urban structure and demographic factors, $\frac{Q}{GRP}$ is used as the dependent variable.

A number of variables are tested in order to capture demographic and geographical differences between the counties; these are shown in Table 4 in addition to GRP.

Table 4 Variables tested for inclusion in the final model (2)

Variable	Explanation
X1	Gross Regional Product
X2	Population
X3	Number of Urban Areas
X4	Degree of Urbanization
X5	Size of urban area
X6	Population density
X7	Population density in Urban areas
X8	Proportion of GRP produced in the service sector
X9	Urban Population
X10	City with population over 100.000
X11	Land Area
X12	Proportion of Area is urbanized

The new variables are added to model (1). A stepwise selection process (e.g. Neter *et al.* 1996) starting with the largest (i.e. including the largest number of variables) model possible was used in order to arrive to a final model. (Since some of the variables are combinations of others, e.g. population, population in urban areas and urbanization, they could not all be tried simultaneously. (It is however interesting to point out that the sign and rough size of the estimated effect of GRP on transport volume remains stable throughout the stepwise selection procedure) Since the data used is in panel form (i.e. including observations from several individuals over several time periods) the model will also include county specific effects as well as period specific effects. The county specific effects will capture time invariant effects not captured by the other variables, sometimes labeled unobserved effects (this includes for instance the effect of major transport hubs such as airports and harbors being located within a county). The time specific effects captures otherwise unobserved effects that affects the amount of goods transported in a year in all counties in a similar manner, this could be e.g. business cycle effects (Wooldridge, 2001).

The final model arrived to after the selection process was:

$$\ln\left(\frac{Q}{GRP}\right)_{i,t} = \beta_1 \cdot \ln X1_{i,t} + \beta_6 \cdot \ln X6_{i,t} + \beta_7 \cdot \ln X7_{i,t} + \beta_9 \cdot \ln X9_{i,t} + \lambda_i + \delta_t + \varepsilon_{i,t} \quad (2)$$

Where, λ_i is the county specific effects and δ_t are the time specific effects. The model was estimated by fixed effects estimator (FE). (Wooldridge, 2001) The individual effects, as well as the time specific effects, were found to be jointly significant. The error term ($\varepsilon_{i,t}$) was also tested for spatial autocorrelation using Moran's I (Moran, 1950, Cliff and Ord, 1973) with no indication the phenomenon found. This indicates that even though the data shows geographical patterns, the explanatory variables included in the model (including the county specific effects) are enough to account for them.

Since the model explains transport activity within a specific geographical area it can be classified as a direct (demand) model for transport activity (as opposed to multi-stage models) which is commonly used in relation to passenger transport modeling. Both model (1) and (2) can however be compared to the generation step of a multi stage model. (Button and Pearman, 1981, Ortuzar and Willumsen, 2001)

The results from estimation of (2) are shown in Table 5 (the county specific effects are shown in Table 6 and the time specific variables are not shown).

Table 5 Results from estimation of model (2), dependent variable is ln(Q/GRP)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Ln(X1)	-1.657091	0.578663	-2.863656	0.0047
Ln(X6)	-1.904139	0.724177	-2.629385	0.0093
Ln(X7)	0.181781	0.084295	2.156480	0.0324
Ln(X9)	2.559596	1.233213	2.075551	0.0394
	Effects Specification			
Cross-section fixed (dummy variables)				
Period fixed (dummy variables)				
R-squared	0.814858			
Adjusted R-squared	0.780144			

As can be seen in equation (2) and in Table 5, short distance freight transport is explained by economic activity (GRP), population density, population density in urban areas and urban population (in addition to the county specific and the time specific effects). The most striking result is that the coefficient for GRP is negative, implying that an increase in GRP of one percent will actually decrease the amount of goods transported within the county by 0,66 percent (goods/GRP will decrease by 1,66 percent) keeping the other factors constant. However, this should not be interpreted as if the total amount of transport demand generated in an urban area is decreasing with production since goods transported into the county from outside is not included in the model. Increased population in the urban areas appears to have a positive effect on the amount of goods transported while higher population density decreases the amount. At a first glance it might appear strange that population density in the urban areas have a positive coefficient implying that denser urban areas result in more goods transported. However, one must keep in mind that this is keeping all other variables (e.g. overall population density and urban population) and the result might be explained by the fact that a larger urban area implies higher generalized costs perhaps resulting in fewer goods transported.

The average individual effect (average λ_i) is found to be 5.6 and Table 6 show how the individual effect in each county deviates from the average level.

Table 6 County specific effects

COUNTY	Effect
Stockholm (AB)	2.02
Uppsala (C)	0.57
Södermanland (D)	0.55
Östergötland (E)	0.23
Jönköping (F)	0.34
Kronoberg (G)	0.39
Kalmar (H)	0.16
Gotland (I)	1.66
Blekinge (K)	1.74
Skåne (M)	1.16
Halland (N)	1.41
Västra Götaland (O)	0.16
Värmland (S)	-0.35
Örebro (T)	0.27
Västmanland (U)	0.54
Dalarna (W)	-1.40
Gävleborg (X)	-0.52
Västernorrland (Y)	-0.40
Jämtland (Z)	-2.56
Västerbotten (AC)	-2.38
Norrbotten (BD)	-3.57

The most positive deviation is found in the county of Stockholm (in which the Swedish capital is located) while the negative deviations are found in Norrbotten, Västerbotten, Jämtland, Västernorrland, Gävleborg and Dalarna, all located in the northern parts of Sweden which can be seen if the results presented in Table 6 are compared to the map in Fig. 1. These effects reflect differences between the counties that remain (approximately) constant over the entire time period. A reasonable explanation for the negative deviation in the northern parts is that a comparatively large part of the production value in these counties originates from forestry, mining and manufacturing which are industries from which the production only to a small degree is consumed locally and therefore transported out of the county. It is therefore possible that the county specific effects would have been smaller if a more accurate variable reflecting industry structure had been used.

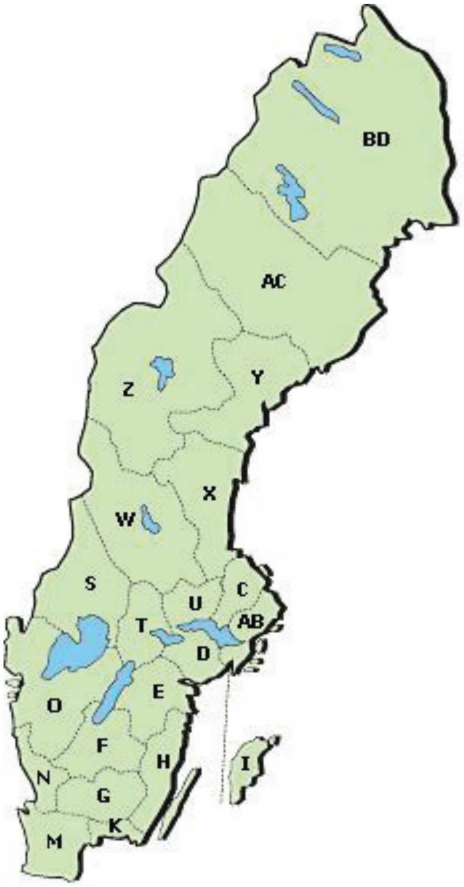

Fig. 1. Map of Sweden and Swedish counties

4. Conclusion

The main conclusion to be drawn is that after controlling for demographic and geographical variables, there is evidence of a negative relationship between the amount of goods transported within a county and the economic activity in terms of Gross Regional Product (GRP). It therefore appears as if at least some of the potential benefits of concentrating economic activities and coordinating transport in urban areas are being utilized. This could be compared to the results of e.g. Dablanc (2007) who found that each type of economic activity taking place in urban areas generates the same amount of goods transported regardless of the structure of the urban area. Since the industry structure (type of activities) vary between counties one should interpret the results somewhat carefully, however the individual specific effects should capture these differences and the results from the present study can therefore be seen as contradicting Dablanc (2007).

Although naturally limited by the fact that not all kinds of activities can be localized in urban areas there nevertheless seems to be possible to combine high levels of economic growth without it resulting in increased volumes of goods transported locally.

In order to further generalize the results, this issue needs to be further investigated. Data from countries with higher population density and larger cities needs to be studied. The material from Sweden should also be further analyzed in order to see if the model could be refined, e.g. could the industrial organization be modeled more precise by classifying industries into several categories instead of just services and non-services.

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