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Ex- post Analyses of Spatial Effects due to Changes in Transport Supply, a Literature Review

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Abstract

Changes in transport infrastructure or its supply have spatial effects. This paper is a literature study that focuses on the effects on economy and population. There have been several attempts and ways to explain these influences, but a general overview on the recent achievements in developing such approaches further and make them more reliable is lacking. This study addresses four main challenges: Measurability of effects (including data availability and intensity), quantification, isolation from other potential factors, and causality.

This work was initiated by the Swiss Federal Office of Spatial Development and analyses Swiss and international approaches. It addresses ex-post assessments of transport-space systems and aims in providing evidence for policy and administration.

Keywords

Spatial effects of transport – ex-post analyses – literature review – causality – ARE

1. Introduction

Transport studies, transport planning or transport engineering as such are very diverse and interesting research branches, but transport and anything within transport – for example changes in rules, networks, behaviour or technology – effect and are effected by economy, society and environment. Whatever happens in this complex interplay of economy, society, environment and transport obeys a (particular) spatial structure and can be captured by spatial models.

The questions become what temporal and spatial dynamics this interplay follows; how to quantify, isolate and explain partial impacts in terms of cause and effect. This paper is written on the assumption that transport plays a central role. Transport is admitted to be embedded in a spatial structure of economy and society, while acting as one of its main drivers. The perspective goes beyond transport as an isolated phenomenon and rather focuses on the exact effect to economy and society. The environmental aspect is excluded from this paper.

In an even broader context and linking to my STRC paper of last year (Fuhrer, 2015), transport supply can be described as a public infrastructure or institution such as schools, laws or hospitals, which enable a state to reach certain aims, making them to the physical substance of territory.

1.1 Overview

This section includes two topics, first a historical overview on transport and its spatial effects and second the extent and characteristics of this literature study. Within the exploration of transport and its spatial effects, three main ideas are important (Thisse, 2011):

1. land use and urban economics (von Thünen, 1826): this line of research answers the question which activity takes place in which spot. Originally concerned about agricultural production and the flows of goods and money between a market town and its hinterland, it nowadays covers everything from land prices of soil to attractiveness of a neighbourhood compared to the rest of the town. The central idea is that transport is needed for personal economic success but comes at costs. The economic conditions of producers (goods, services, labour positions etc.) and consumers characterise how they respond in terms of spatial decisions to the structure of transport costs.

2. the nature of competition across space (Hotelling, 1929): this line of research deals with the spatial form of general equilibrium theory. Every piece of space can only be used by one agent (firm, person, state) and space is a limited resource. Also, the decision for or against a specific spot is strategic as some of the spots are more desirable than others, for example

because they provide better access to customers (company) or friends (household). But these characteristics depend on the decisions of all other agents. This means there is a competition (game) and an equilibrium. The fundamental question becomes whether it is favourable for agents to cluster with or rather to separate from each other.

3. new economic geography and the emergence of economic agglomeration (Krugman, 1991): this line of research brings together location theory and international trade theory. It aims in explaining regional patterns. One important feature is the modelling of dispersion and agglomeration which interacts with the mobility of production factors and the spatial distribution and structure of consumption. Decreasing transport costs even allow agents to "split" themselves, meaning they figure in one spot as a production factor (for example as a worker) and in the same time figure as consumers in a spatially separated spot. On a higher level, different regions as a whole figure as specific locations for production ("clusters") or consumption, depending on transport supply.

To summarise, in all three lines of research which have been evolving in the last 200 years or so transport, its supply and costs, plays the fundamental role in what can be observed by looking at space. In other words, transport is a very intuitive, elegant and reliable variable to explain spatial patterns of society and economy. This paper provides an overview on the recent advancements in these very approaches that aim in explaining such spatial patterns.

The selection of papers is limited to questions related to society and economy. They can be Swiss or international and academic or by public or private organisations. They should be recent and look at regions or variations within countries, if possible at a spatial resolution of municipalities. Questions of interest are the measurability of effects (including data availability and intensity), quantification, isolation from other potential factors, and causality.

Figure 1 shows categories of effects due to transport on economy. The category *direct transport supply* is not covered in this paper, *direct transport demand* and some of *indirect macroeconomic* categories include the main topics of interest. Similarly, Figure 2 explains the most relevant effects on society. Here, this paper focuses on *severance/social cohesion, availability and physical access, access to spatially distributed services and activities*; the others are of a rather classic cost-benefit-analysis character and are excluded in this paper.

Figure 1 Economy: commonly examined effects

Direct transport supply	*Direct transport demand*	*Indirect microeconomic*	*Indirect macroeconomic*
– Income from transport operations (fares and salaries)	– Improved accessibility	– Rent income	– Formation of distribution networks
– Access to wider distribution markets and niches	– Time and cost savings	– Lower price of commodities	– Attraction and accumulation of economic activities
	– Productivity gains	– Higher supply of commodities	– Increased competitiveness
	– Division of labor		– Growth of consumption
	– Access to a wider range of suppliers and consumers		– Fulfilling mobility needs
	– Economies of scale		

Source: Rodrigue et al. (2006)

Figure 2 Society: commonly examined effects

Theme	Sub-themes	Impact
Presence of infrastructure	Structurally	Visual quality
		Historical/cultural resources
		Severance/social cohesion
	Temporarily (construction)	Noise nuisance
		Barriers and diversions
		Uncertainty of construction
		Forced relocation
Presence of parked vehicles		Visual quality
		Use of space
Presence of transport facilities, services and activities	Transport facilities	Availability and physical access
		Level of service provided
		Transportation choice/option values
		Cultural diversity
	Land use	Access to spatially distributed services and activities
Traffic (movement of vehicles)	Safety	Accidents
		Averting behaviour
		Safety perceptions
		Public safety (dangerous cargo)
	Environment	Noise levels, nuisance
		Soil, air and water quality
Travel (movement of people)		Intrinsic value, journey quality
		Physical fitness
		Security

Source: Geurs et al. (2009)

1.2 Structure of the paper

The remainder of this paper is structured as follows. Section 2.1 reports on the collection of suitable papers and section 2.2 presents the classification: some lines on classification possibilities and an overview on publicly available papers by non- academic authors and a few prototype-like papers by academic authors. Section 3 provides some concluding points on all reviewed literature and in the end presents a comparison to the current method at ARE (section 3.1). A complete list of literature is in section 4.

2. Method and Classification

The idea and funding of this literature study are by Martin Tschopp and Matthias Kowald of the Federal Office for Spatial Development (ARE). Such questions are regarded as important for future spatial strategy plans and considerable scientific advancement is assumed to have been happening. Currently, it is hard to find quantitative approaches and thus these recent findings should be investigated and integrated into a report for ARE.

2.1 Method

The method consists of collecting relevant literature from academic journals and publications as well as from private and public institutions that work in the field of transport and spatial development. All literature is viewed, classified and summarised into main findings and problems.

While some publications by academic publishers could be obtained, there was hardly any material available by other sources. Therefore, a number of currently 110 persons in several state, private and semi-public institutions were contacted. Most of these contacts are based in Western Europe and Northern America. The author of this paper contacted most of them directly, some of them in a second round on recommendation by the previously contacted persons. They usually are governmental offices for transport, economy, environment, planning, statistics, finance or sometimes other topics and in most cases are national/federal offices. For larger or divided countries, such as the US, Spain, Belgium, Germany and so forth, also offices on a lower level (state, region etc.) were contacted. In other cases, private organisations or organisations that work for governmental offices were contacted too. Whenever possible, the specific person(s) in charge were contacted, else the office in general.

80 contacts out of the 110 e-mailed contacts have not replied during March to May 2016.

2.2 Classification

The reviewed papers differ regarding their method approach and foci of effects. This is either due to theory, data availability or research question. In terms of method, the following approaches are possible:

1. Instrumental spatial variable: a spatial variable which correlates with an explanatory spatial variable but does not correlate with the spatial error term. It is a way to deal with omitted variables, endogeneity and cause-effect problems. They usually are hard to find.

2. Spatial treatment group: divide the spatial sample of observations into two groups, which have identical characteristics except for the spatial explanatory transport variable from which you expect the effect on space to happen. It is a way to quantify and isolate a specific effect from a general development. Generally, it is almost impossible to achieve entire similarity of the two groups. A related method are shift-share regressions, where different regions within a larger space are compared to each other.
3. Spatial model: a model that describes the transport-space interaction. This is a way to account for all relevant variables, to understand individual effects and identify cause and effect. Such models need to be calibrated and there is a trade-off between general transferability and specific cases.
4. Spatial time series: approaches that take into account multiple measurement points in time of the same spatial object. This is a way to isolate an effect and to deal with cause-effect problems by capturing temporal variance. As there are spatial *and* temporal interdependencies, the data structure needs to be very well modelled.
5. Various spatial approaches: there are several techniques by neuroscience, network theory, landscape genetics and so forth that have similar problem situations and solutions. Another prominent concept are hedonic prices. All these approaches can help to quantify, isolate and define causality in transport-space interaction. They usually need to be adapted to the specific transport-related situation.
6. In addition, natural experiments can answer such research questions. This is when, in a real situation for independent reasons, the changes in transport happen in such a fashion that one can extract information on the effects due to transport supply changes. A technique of 1. to 5. or another one could be used to capture the effects.

Besides the technique, there are thematic categories as well. There is the principal distinction between economy and society as presented in Figure 1 and Figure 2. Based on the reviewed papers, the following issues are commonly considered in pure and related transport-space effect studies

- land prices, property prices
- residential location choice, density, urban sprawl
- commuting, time budget
- spatial distribution of demographic characteristics: wealth, age, ethnicity etc., self-selection
- transport costs, market size, trade, specialisation
- land prices, firm location choice, labour pool, labour market
- density, agglomeration, productivity
- dependencies, production chains, outsourcing

- competition, cost pressure, rationalisation
- globalisation, overcoming borders

The subsequent table, Table 1, gives an overview on different papers written by non-academic authors (first part) and by academic authors (bottom part). Various of the topics listed above are addressed. The academic papers are only a selection from a much larger amount of papers. They act as a typical representative paper for a group of papers that are similar and differ only in minor characteristics.

Table 1 Publications found by non-academic institutions (first part); selected prototype-like academic publications (bottom part)

Publication	Institution	Method	Theme
(Stone et al., 2010)	Asian development bank institute	Freeware: Global Trade Analysis Project model (multi-regional general equilibrium model), augmented	Modelling the effects of transport investments on regional GDP development and the reduction of poverty (measured as people's income below a threshold, surveyed) in the Mekong area. No ex-post analysis stricto sensu.
(AECOM, 2014)	Department of transport, tourism and sport Ireland	Qualitative: interviews with various stakeholders	Quantifying the wider economic benefits of a major road project and a rail project near Dublin. Interviews reveal that the actual benefits of the projects are higher than in the then calculated cost-benefit analysis due to agglomeration effects etc., however they "cannot currently be quantified".
(Charlier et al., 2016)	Region Wallonie, institut de l'évaluation, de la prospective et de la statistique	Descriptive: GIS analyses	Analysing the structures in territory, Wallonie and Bruxelles region. Comparing them to changes in residential location choice and the forming of residential pools (agglomerations) between 1994 and 2013.
(Economic and Financial Evaluation Unit, 2014)	Department of transport, tourism and sport Ireland	unknown	Quantifying the advantages of several road and rail projects between 2006 and 2010 in Ireland. While classic cost-benefit analysis variables are covered, it is unknown how additional variables are modelled.
(Eliasson, 2012)	Swedish agency for growth policy analysis	Treatment group, on both side of the support area's boundary	Quantifying the effects of the Swedish regional transport grant between 1997 and 2009 for remote areas by looking at the outcome in terms of work places in saw mill industry on treated and untreated group
(Falcidieno et al., 2013)	ESPON	Panel data, Granger tests, further tests with subsets	Quantifying the effects of regional airports in Europe 1991- 2010 on regional growth by capturing accessibility gains.

Publication	Institution	Method	Theme
(Giffiner et al., 2012)	ESPON	Urban growth model	Examining the chance in urban size in terms of urban benefits and costs (transport covered indirectly only) in Europe with data 1990 to 2006
(McKenzie, 2015)	U.S. census bureau	GIS and descriptive analysis	Modelling the development of socio-demographic characteristics of neighbourhoods in proximity to a rail stop compared to some without access to rail during the years 2006-2008 and 2011-2013.
(National Economic Council, 2014)	U.S. national economic council	Descriptive	Exploiting case studies of major road projects from various states to obtain estimates for for example the production of jobs.
(PWC, 2015)	Region Wallonie, direction générale opérationelle des routes et des bâtiments	Descriptive	Quantifying the socio-economic effects due to investments into transport infrastructure. The report documents the investments and the development of transport infrastructure and socio-demographic characteristics; it mentions numbers to effects, however it is unclear whether they reflect the situation in Wallonie.
(Saxton, 2015)	Transport analysis (office, Sweden)	Qualitative	Examination of the effects of state financed transport grants in Scandinavian countries and their benefits. Comparison of the different national models and their outcomes.
(Sund-Baelt, 2015)	Sund & Baelt, operator of Storebaelt tunnel	Unknown (in Danish only)	Estimating the socio-demographic impacts, population distribution and wider economic effects.
(Charlier et al., 2011)	Region Wallonie, institut de l'évaluation, de la prospective et de la statistique	GIS, descriptive	Examining where new houses were built in Wallonie between 2001 and 2008 and linking this to public transport service and accessibility.

Publication	Institution	Method	Theme
(Baum-Snow, 2007)	University	Spatial instrumental variable	Quantifying the effect of the US interstate highway construction on population development in core cities.
(Hornung, 2012)	University	Spatial instrumental variable, fixed effect etc.	Quantifying the effect of railway construction in Prussia on population growth between 1841 and 1870.
(Maciel and Biderman, 2013)	University	Treatment group, hedonic prices, difference-in-difference	Quantifying the effects of a ring motorway around Sao Paolo on land prices between 1985 and 2006.
(Álvarez and Blázquez, 2014)	University	Frontier technique, panel regressions with fixed effects	Quantifying the effects of motorway construction in Spain during 1980 to 2007 on regional productivity growth analysing the value of built road infrastructure and the development of total factor productivity decomposed as technical advancement and efficiency.
(Geurs et al., 2012)	University/ private research company	Integrated land-use transport model (LUTI)	Quantifying the effect of accessibility change (transport and population) on relocation of population and work positions and estimate monetary values for these benefits. No ex-post analysis stricto sensu.
(Gjestland et al., 2012)	University	Hedonic prices	Quantifying the effect of a new bridge in Norway on property prices and capturing the regional pattern of accessibility gains in monetary units during the time 1992 to 2009.

The table above, Table 1, includes all relevant publications by non-academic institutions. There are more papers sent to the author of this category, but they did not fit into the scope of this literature review. Even some of the listed above do not entirely fit, but coincide with most of the aspects dealt with in this paper. The list of academic papers would be much longer; the ones listed above are prominent examples and represent each important tools or techniques in spatial econometrics or the analysis of transport-space interactions in general. The complete list of reviewed academic papers is in the reference list in section 4. To provide some more details regarding the academic papers, there are summaries to some of them.

Baum-Snow (2007): This is a study how the US interstate highway network effected suburbanisation. It analyses the development of core cities and their suburbs in metropolitan areas during 1950 and 1990. The explanatory transport variable is the number of rays per core city. An spatial instrumental variable (IV) is used: a network map of the planned interstate highway network from 1947. The explanatory variable strongly correlates with the IV since the actual network was mostly built according to the plan. The dependent variable does not correlate with the IV as the historical plan was mostly based on economic and military reasons rather than the development of suburban regions. Without the construction of the interstate highway network, US core cities would have grown by 8% instead of an actual decline by 17% during the observed 40 years.

Hornung (2012): This paper follows a similar approach as Baum-Snow (2007). In addition, they look at in between places – all places execpt start, end and crossing points of railway lines. The reasoning is that these places were not intended to be served by rail but by chance because they are located in between are served by rail.

Maciel und Biderman (2013): This is a study on the announcement, construction and opening of a ring motorway around Sao Paolo. As the motorway was opended in sections, treatment groups can be defined to capture the accessibility effect. Using a computed indicator for land prices at several time steps during the 20 years of the examined period, the difference-in-difference approach can be used for hedonic prices. Observations can be classified according to their distance to ramps to the motorway. Properties on the outside of the motorway and in close distance to ramps increased in price of up to 133%. Similar lots, but on the inside of the motorway lost in value.

A more detailled and comprehensive overview will be available in the report for ARE (forthcoming).

3. Conclusion and Recommendation

Having reviewed published papers in the field of ex-post analyses of spatial effects due to changes in transport supply, there are several concluding findings.

1. Quantitative approaches using techniques such as spatial instrumental variables or hedonic prices started to occur in the academic literature approximately ten years ago.
2. The amount of such studies is fairly modest. This is in contrast to numerous studies that describe how to produce reliable forecasts of transport demand from spatial developments.
3. The biggest pile of papers originates from academics, only a small share is written by governmental bodies.
4. Nevertheless, the issue is present in reports by state agencies and similar institutions. However, with very few exceptions, these documents follow qualitative research, are descriptive only or have ex-ante character.
5. In state offices, a clear responsibility seems an important condition. While a few contacted institutions had a clear place where such questions were dealt with, others did not and forwarded the request to other authorities. Being an interdisciplinary topic, it is either outsourced into an isolated office, such as an evaluation unit or semi-state institution, or it is located in a powerful authority such as Department of Transport or Department of Economics rather than in departments for rural affairs, planning or environment.
6. A lot of contacted institutions did not reply. This could be either because they did not understand the request, regarded the topic as unimportant or did not have any material to contribute.
7. Data seems to be a relevant bottleneck in that kind of studies. Many researchers mentioned that only because certain data was made available to them, they could answer their research question. This seems especially crucial for time-series *and in the same time* spatial data on suitably high resolution.
8. Beside good data sources, various statistical tests and techniques as well as combinations thereof are needed to produce reliable and robust results. To be precise, one needs to invest in a convincing identification strategy and in corroboration of the produced results.
9. Certain effects can only be measured in a quantitative and spatially explicit way using these techniques.
10. No study concludes that the transport effects on space were negligible. As most of the review publications are academic papers, there might be a trend towards reporting if the data shows an effect rather than if the data does not show any effect. However, as

in most cases this effect is substantial and well explained through theoretical models, this result seems reliable.

11. Most studies cover three points in time or more, a considerable amount do this over two decades and more; as the effects are assumed be slow.
12. Most frequent topics are the reallocation of population and labour and changes in regional growth.

Overall, it seems that this new generation of spatio-temporal analyses depend on elaborated tools and techniques on the one hand and on the other hand on large and good data sources. Academic authors have started to use them first, very few non-academic authors have followed them. Even though, they expand the repertoire of research questions substantially. So far, most studies have used time-serial data and addressed questions in reallocation of population and labour as well as changes in regional growth.

3.1 Comparison to ARE

ARE currently uses the so called Tripod approach, as evaluated (Güller and Güller, 2007a) and categorised (Güller and Güller, 2007b) nearly ten years ago. It allows to conduct standardised analyses and to examine spatial effects due to transport on different aspects in society, environment and economy. However, it is limited in terms of quantitative results and causality.

Compared to other publications by non-academic authors, the Tripod approach seems in a good position as it is equally able to explain spatial processes. However, on comparison with recent papers written by academic authors it is one or two steps behind them, especially regarding isolation and causality. But this seems to be a general problem, not only an ARE-specific one. It would need to include more complex spatial econometric techniques such as spatial instrumental variables and for anything based on hedonic prices information on land and property prices need to be at hand.

4. Literature

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