

Wider Economic Impacts of Accessibility  
– a Literature Survey

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*Abstract:*

This paper starts out with by discussing the definitions of Wider Economic Impacts/Benefits and regional development. Each area where WEIs could be present is then treated: economic growth (production and cost function studies), labour market (agglomeration, labour supply), commodity market and housing market. A theoretical background is given, the empirics are summarized and the relation to CBA is discussed.

*Keywords:* wider economic impacts, wider economic benefits, regional development, cost-benefit analysis, agglomeration, labour supply, labour market, housing market, commodity market.

*JEL Codes:* R4, D61, E24, H40



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## 1 INTRODUCTION

The impact of infrastructure on growth, labour, housing and commodity markets is widely discussed. The discussion goes back at least to Adam Smith (1776) and Alfred Marshall (1890) who observed that productivity increases with city size and density. The scientific debate has become more intense since Aschauer (1989) presented an econometric model on the relationship between production and public investments.

In this literature review we aim to give a theoretical background, summarize the empirical findings and discuss to what extent these impacts from infrastructure are included in cost benefit analysis. Since the founding for this paper comes from the Swedish Transport Administration, some attention is given to Swedish practises. The paper is divided into sections that discuss growth effects, labour market effects, commodity market effects and housing and land market effects.

The most widespread name on these types of effects today is wider economic benefits (WEB) or wider economic impacts (WEI). There is no clear difference made in the literature between WEB and WEI. In recent years WEI seems to have gained in popularity, probably depending on the fact that the effects can be both positive and negative. WEB/WEIs are caused by the existence of market imperfections in transport-using industries. These imperfections imply that the values individuals place on accessibility changes may differ from those placed on it by society. The relevant market imperfections here are only those in the transport-using industries, i.e. benefits from accessibility changes that are not captured in the cost benefit analysis (CBA). According to this definition social inclusion could be included in WEI, but that is not the case in literature. Social inclusion is a shorthand label for an extremely complex problem: what happen when individuals or areas suffer from a combination of linked problems such as unemployment, poor skills, low incomes, poor housing, poor access to education, high crime environments, bad health and family breakdown (OECD, 2002). One probable reason for not including social inclusion in WEI is that the effects are social rather than economic. Externalities such as pollution, accidents or congestion are already captured in the (CBA), these are referred to as external effects, not WEI. Producer surplus in transport CBA refers to effects on operators and by its inclusion in traditional CBA it is not included in WEI (transport using industries are included in WEI, not transport producing industries).

“Regional development” refers approximately to the same thing as WEI but is not as precisely defined. Region could refer to uniform or homogeneous regions (linked by certain uniform characteristics), nodal regions (emphasizing the interdependence of different components within the region) or programming or planning regions (reflecting established political or administrative boundaries) as originally defined in Richardson (1969). Development usually refers to competitiveness, trade or wealth. One difference between regional development and WEI is that the former also includes effects that are included in the CBA.

In this paper we will focus on WEI, defined as effects on the economy caused by the existence of market imperfections in transport-using industries. Wider implying effects not captured in the CBA, i.e. the imperfections in the sense that the values individuals place on accessibility changes may differ from those of society. The type of CBA referred to here is a partial analysis of the transport sector, which assumes perfect competition. Perfect meaning that the goods are homogenous, that no buyer or seller can affect prices, that there are no transaction costs or asymmetrical information. This implies that all benefits could potentially be measured in the transport market ("on the road"). In this paper we will also treat spatial computable general equilibrium analysis (SCGE), which relaxes the partial equilibrium assumptions by modelling the surrounding economy.

Each chapter in the paper treats one area where WEIs could be present: economic growth (production and cost function studies), labour market (agglomeration, labour supply), commodity market and housing market. This practical division leads to some theoretical overlaps. All chapters start with a theoretical overview, continue by summarising the empirics and ends with a discussion about the effect on CBA. Our aim has been to include all WEIs of importance, but since we do not aim to prove this statement with an all including theoretical model there is a possibility that we have missed something.

## 2 ECONOMIC GROWTH

The recent decades have seen an extensive increase in macroeconomic literature concerning the economic impacts of transport infrastructure. The macroeconomic strain of research uses a top-down approach to account for the effects of transport infrastructure while the traditional CBA is based on microeconomics.

Advocates of the macroeconomic approach claim that externalities to investments in infrastructure are not (fully) captured in traditional CBA studies. On the other hand some argue that the macroeconomic approach is a “black-box” since the use of production functions does not include behaviour of economic agents. The estimation of cost function is better in this respect since duality ensures behaviour.

Lakshmanan (2011) summarizes the important contributions in this literature. In his paper the works of Mera (1973), Aschauer (1989) and Nadiri and Mamuneas (1996) are described. In addition there are several meta-studies who give an overview of this literature (see Melo et al. [2013]).

To address the estimation of the magnitude of the impact of transport infrastructure there are two main approaches. The first is the production function approach while the second is referred to as the cost function approach.

### 2.1 Production function

#### Theory

When trying to determine the linkage between transport investment and economic output many authors have used the production function approach. The production function explains how inputs like labour, capital, transport investment and other components influence output. A general representation of such a function may be:

$$Y = Af(K, L, G, T)$$

Where Y is output, A is total factor productivity (TFP), K is private capital, L is labour, G is public capital excluding transport infrastructure and T is transport infrastructure.

The general idea is that if the relationship between increases in transport infrastructure (T) and output is positive and significant, then transport infrastructure is a determinant of output. To determine the magnitude of transport infrastructure influence on output it is common to use the elasticity of output with respect to transport infrastructure. The elasticity of output,  $\epsilon_T$ , (with respect to transport infrastructure) is the percentage change in output when transport infrastructure increases by 1 percent.

$$\epsilon_T = \frac{dY}{dT} \frac{T}{Y}$$

In the literature it is most common to assume that  $f(\cdot)$  is some form of constant elasticity of substitution function (CES). The Cobb-Douglas functional form is widely used. The reason for this common assumption is that the elasticities of output have straightforward interpretations.

Melo et al. (2013) point out a wide range of sources for the variability in results from studies of production functions. The sources can be summarized by three main reasons. The first is differences in the model specification and consequences of modelling choice. The second is the time and scope of studies. The last is the variation in data used for estimating the elasticities. See e.g. Melo et al. (2013) and Hansen (1965) for an overview.

### **Empirical work**

There is a vast production function literature. Following is a review of the most influential works and some recent studies.

Mera (1973) were the first to study the impact of public infrastructure through the use of the production function framework. Using data for regions in Japan in the 1950's and 1960's he found output elasticities of 0.35 for the manufacturing sector and 0.40 for the service sector.

Aschauer (1989) estimated large returns to investments in the public capital stock, with an elasticity of 0.39. However, the strikingly high estimates soon were questioned on methodological grounds. In a thorough literature review, Romp and De Haan (2007) account for a vast number of studies following Aschauer's paper. Concerns about the order of causality between public capital and economic output, along with considerable developments in econometric modelling, has motivated new approaches in estimating returns to public capital formation. In particular, the use of vector autoregression has become a popular tool for time-series estimation, as it requires fewer assumptions on the order of causality, and allows many types of econometric specifications. From their literature review, Romp and de Haan (2007) make three conclusions: that there is more consensus in the recent literature than previously, that the estimated return to public capital investment is much lower in recent studies than in previous studies and that the results vary considerably between regions, countries and industries.

Calderón et al. (2012) uses panel time-series approach on a large cross-country data set. The paper estimates a long-run aggregate production function with human capital, physical capital and a synthetic measure of infrastructure comprising transport, power and telecommunications as variables. The measure of transport infrastructure is total length of the road network (in kilometres). The authors present estimates of the output elasticity of infrastructure in the range of 0.07 to 0.10.

Two recent studies (Melo et al. [2013]; Ligthart & Martin-Suarez [2011]) conducts meta-analysis on the relation between public capital and economic activity, where the average elasticity is 0.06 and 0.2, respectively, and the median elasticity is 0.01 and 0.13, respectively. The sample of studies is quite different in

the two meta-analyses (the two meta-studies cover 49 and 33 studies respectively, but only 9 are used in both), which explains the variation of results. Furthermore, the samples are primarily constituted by studies from the 1990's, indicating that the results, while clearly demonstrating lower estimates than those of Aschauer, is not a reflection of today's most sophisticated estimation procedures.

### **Relation to CBA**

The main difference between traditional CBA and the production function approach is the scope of the analysis. The CBA is based on microeconomic theory and describes the direct and indirect time and cost savings and the externalities associated by transport. The production function approach is on the other hand based in macroeconomic theory. The estimates of the output elasticity (with respect to transport infrastructure) are measures of how the transport infrastructure influences economic performance in a more general sense. If traditional CBA underestimate the effects of transport investment (because of wider economic impacts), then estimates based on the production function approach should in theory include the wider economic impacts. The problem with the production function approach is the spread in estimates of output elasticities, both in respect to magnitude and direction. In addition the lack of economic behaviour in the production function approach imposes uncertainty about the results.

There is also a difference in the question asked. Production function studies try to answer the question "is society over- or under supplied with infrastructure" while CBA tries to give advice on whether to carry out a specific investment.

## **2.2 Cost function**

### **Theory**

An alternative to the production function approach is the cost function approach. The key difference from the production function approach is that cost function models behavior of firms. The representation of a cost function may be as follows (see Cohen (2010)):

$$TC = VC(Y, P_{LP}, P_{LN}, P_M, K, I, t) + P_K K + u$$

Where TC is the total cost of production, Y is output,  $P_{LP}$  is the wages of productive workers,  $P_{LN}$  is the wages of non-productive workers,  $P_M$  is price of materials inputs, I is infrastructure stock. The stock of private capital is K and when private capital is modeled as a variable input their associated prices are  $P_K$ . Regression analysis of cost functions is used to estimate parameters necessary for obtaining elasticities of production costs with respect to transport infrastructure.

Lakhsmanan (2011) points out four advantages using the cost function approach compared to the production function approach. First, the ability to provide substitution elasticities between inputs. Second, the cost-function approach allows a direct estimation of the effect of infrastructure on input demand. Third, joint estimation of the cost function and the derived demand for inputs increases the degrees of freedom, allowing improved statistical precision. Fourth, the ability to derive the marginal benefit of infrastructure, as well as the optimal level of infrastructure, yielding a richer analytical framework to be developed with the cost function approach.

### **Empirical work**

Despite the appeal of the cost-function approach, the empirical literature is scarce. A key reason is that the flexibility in econometric specification demands large data sets to be robust (Romp & de Haan, 2007).

Nadiri and Mamuneas (1996) developed a macroeconomic model estimating cost- and demand functions for 35 different industries, for the years 1947-1989. The overall aggregate cost elasticity for all sectors was estimated to -0.04, and the output elasticity 0,051. The return to highway capital was found to be exceptionally high in the early period of the sample, reducing to the same rate as for private capital in the 1970's and 1980's. The results of significant negative cost elasticities and positive output elasticities are replicated for a number of other countries (UK, Japan, France, Germany, Mexico, and India).

Cohen (2010) argues that advances in spatial econometrics has allowed for estimations that are sensitive to spatial interaction, such as autocorrelation, lags, and spatial multipliers. Generally, while the results vary with location and econometric specification, the precision of estimates on the effects of infrastructure investments on production costs has increased since the early 1990's. Cohen and Morrison Paul (2004) estimate the cost-saving productive effects of infrastructure investments using a cost-function model on manufacturing industry data across American states, for the years 1982-1996. They find significant positive productive effects from infrastructure investments, with decreased materials costs as the driving factor. Cost savings are greater in the continental states than in coastal states. A key insight from the results is that inter-state cost savings augments intra-state cost savings. Therefore, models which do not include spatial spillovers from infrastructure investment will underestimate the effect for the manufacturing sector. Similarly, Moreno et al (2004) use data from 15 Spanish regions for 1980-1991, concluding that infrastructure investments lower costs for intermediate products, but leads to higher labour costs.

### **Relation to CBA**

While the production function approach differs a lot from CBA, the cost function approach includes much of the same ingredients as the consumer surplus of freight owners in CBA. The cost function approach includes economic behaviour because of duality. Compared with the production function approach this is a tractable trait of these models and is a similarity to the micro-based CBA.

In traditional CBA the impact of infrastructure on generalized transport costs is the source of benefits of infrastructure. The generalized transport costs (GTC) includes direct costs (i.e. tolls or tickets), distance- and time dependant costs. If some measure of the distance-dependent costs is included as a variable in the estimation of a cost function there will be some overlap between the cost function and the GTC.

In theory the cost function approach could be used in a similar way as CBA to estimate the effect of an infrastructure investment. If the elasticity of total costs (with respect to transport infrastructure) yields a reduction (i.e. is negative) in costs when improving transport infrastructure this could be compared with the reduction in GTC in a CBA. In the literature the scope of the estimation of cost functions is more on the macro-scale and offers no evidence of the similarities and dissimilarities of the cost function approach and CBA.

Theoretically, if the same transport infrastructure project is studied using the cost function approach (assuming that the cost function measure the same as the CBA) and CBA, and the cost function approach predicts a greater reduction in costs than CBA this could be viewed upon as wider economic benefits. The main problem with this hypothesis is the uncertainty of what is included in the cost function and GTC, respectively.

### 3 LABOUR MARKET

In this section we discuss how investment in transport infrastructure may cause wider economic impacts through the labour market. An improvement in transport infrastructure may give effects through the labour market because of the existence of agglomeration economies. Agglomeration is based on the observation that productivity grows with city size or density. The second effect which transport infrastructure may influence the labour market is through the labour supply in the economy given a static housing market. A reduction in travel time, and thereby travel cost, may result in an increase in production since more time is used in production rather than travelling.

Some also argue that a geographical redistribution of workers to more productive jobs is an effect that should be included as wider economic impacts. The idea is that there is a net positive impact from moving workers from a low productivity area to a more productive area. We consider this effect as included in the agglomeration effect, and hence do not discuss this effect in detail below.

#### 3.1 Agglomeration

##### Theory

Agglomeration in economic term refers to the effect of economic concentration on productivity. There is lots of empirical work that shows the relation between productivity and city size. Agglomeration caused by improved transport infrastructure can be argued on the basis that the infrastructure increase accessibility of an area thereby making it available for a greater number of workers (and firms). This will increase the economic concentration in the affected areas and may thereby increase the level of agglomeration. The positive relationship between agglomeration and productivity is then the reason for the effect. Chatman and Noland (2011) provide a good overview of the relationship between transport infrastructure and agglomeration with emphasis on the role of public transport.

Literature identifies three main micro-foundations of agglomeration that cause increased productivity. These mechanisms are matching, learning and sharing (see Duranton and Puga [2004] for an overview).

- Matching – The matching mechanisms may improve the expected quality of matches or the probability of matching in the labour market. Matching may also alleviate search unemployment in the labour market.
- Learning – The learning mechanisms are based on the generation, the diffusion, and the accumulation of knowledge in agglomerations. The general idea is that by bringing together a large number of people (and firms), it will be easier to facilitate learning.
- Sharing – The sharing mechanisms stem from sharing indivisible facilities, sharing the gains from the wider variety of input suppliers that can be sustained by a larger final goods industry, sharing the gains from specialization that can be sustained with larger production, and sharing risks.

There is an immense literature with different theoretical approaches to explain the three agglomeration mechanisms. In this paper the focus is on how agglomeration in general may cause effects not captured in the traditional CBA. We therefore focus on papers trying to explain how transport infrastructure, or accessibility, may affect the level of agglomeration, and thereby productivity, in general (not which of the mechanisms above causing the effect).

Most models trying to explain the agglomeration effect of transport infrastructure assume some form of general equilibrium condition. The exception is the effective density approach (see Graham (2007a)). The latter has been the most influential in the development of guidelines for calculating agglomeration effects by practitioners i.e. the Department for Transport in the UK.

In the late 1980s Mills and Carlino (1987) explored the determinants of population and employment densities between regions. The population and employment at a location is in this model determined simultaneously. The determinant of regional differences is the different amenities in different locations. The Mills and Carlino framework have received interest in Swedish research and forms the basis for the Swedish SAMLOK-model.

Venables (2007) is one of the more influential papers on the economic impact of transport infrastructure on agglomeration. In this paper a general equilibrium (urban equilibrium) model is developed to explain the impact of transport improvements on the productivity of workers in urban areas. The first gap between private and social benefits arises because of the positive relationship between city size and productivity (i.e. the level of agglomeration). The papers focus is the general case and not which of the agglomeration mechanisms who cause the effects. The implication of Venables' model is that expanding city employment brings about a positive externality (the agglomeration effect). Additional employment in urban areas raises the productivity not only of new urban workers, but also of existing workers now reaping the benefits of a larger urban agglomeration.

A more recent theoretical work by Kanemoto (2013) extends the model developed by Venables and explicitly models the sources of agglomeration economies and allows cities to be heterogeneous. The source of agglomeration is increased variety in the intermediate goods, and relates to the sharing mechanism in the classification of Duranton and Puga (2004). The paper concludes that the effect of variety distortion on wages is comparable to the agglomeration effect in Venables (2007). Another conclusion is that improvement in urban transportation in one city tends to increase the population in that city but to reduce the populations in other cities. If agglomeration economies in other cities are larger, then the net agglomeration benefits are negative.

It has been argued that spatial computable general equilibrium (SCGE) models offer opportunities for computing wider economic impacts including agglomeration effects in CBA in a theoretically more satisfactory way than other approaches. SCGE models typically are equilibrium models of interregional trade and location based in microeconomics, using utility and production functions with substitution between inputs (see Brocker and Mercenier [2011] for an overview). As early as in 2001 Oosterhaven et al. (2001) present a SCGE model

for the Dutch economy. Since then several SCGE models have been developed across Europe. In Hof et al. (2012) there is an overview of the performance of some of the different models using a hypothetical railway project. The authors conclude that it rather pays off more to concentrate on further improving the calculation of direct effects, i.e. the traditional CBA, than to focus too much on detailed calculations of wider economic benefits.

Graham (2006, 2007a, b) and the Department for Transport (2005, 2012) employ a different framework, unlike the urban equilibrium or the SCGE models, to determine the magnitude of the agglomeration caused by transport infrastructure. The framework hinges on a gravity model-type equation called effective (economic) density. The effective density can in its more general form be expressed as:

$$D_{it} = \sum_{j \neq i} a(c_{ijt})z_{jt}$$

The measure of effective density,  $D_{it}$ , shows how the economic density of an area  $i$  in time  $t$  is a function of a state variable,  $z_{jt}$ , a measure of distance,  $c_{ijt}$ , and a distance decay function,  $a(c_{ijt})$ . The distance decay function explains how more distant areas cause smaller agglomeration impulses than areas more close by. This is based on the assumption that distance makes interaction between firms and people more difficult. To determine the effect of agglomeration of transport infrastructure investment the assumption is that productivity is a function of the effective density parameter ( $D_{it}$ ) and empirically estimate the elasticity of effective density on productivity. To calculate the agglomeration effect of a reduction in distance, i.e. travel time, it is possible to use the difference in effective density and the elasticity.

### **Empirical work**

There is a vast literature on the empirical measurement of the effects of agglomeration. The consensus is that urban scale has a positive and significant effect on productivity with agglomeration elasticities typically found to be somewhere between 0.02 and 0.10 (for reviews see Rosenthal and Strange [2004], Melo et al. [2009]).

There are few empirical applications directly associated with the model developed in Veneables (2007). A simplified model has been used to evaluate the wider economic impacts of transport investments in Norway (see Heum et al. [2011]). Using Norwegian wage data and travel time approximations, the authors find that the effects of transport projects between the cities of Bergen and Stavanger to be 10 bn. NOK annually. However, this paper has received massive criticism based on the assumptions made about the size of labour markets and of the effect of wage equalization across space (Minken [2013]).

The elasticity of the “Samlok” model, used in Swedish infrastructure planning, is 0.044 (Anderstig et al., forthcoming). This is about the same size as a related estimate for UK, reported in Venables (2007). Samlok is based on accessibility

calculations by the national Swedish transport forecast model Sampers (rather than density or size measures).

Elhorst and Oosterhaven (2003) uses a SCGE model to assess four proposed Maglev train projects in the Netherlands. They find substantial wider economic benefits compared to the conventional benefits of a high-speed railway project. The same authors find additional economic benefits to be between +32 percent and +38 percent of the direct transport benefits of the same projects (see Elhorst and Oosterhaven (2008)).

In the empirical literature the effective density framework is more frequently measured than the two types of models described in the theoretical section above.

Mare and Graham (2009) use a longitudinal unit record dataset of firms in New Zealand for a micro-econometric analysis of the impact of agglomeration on the multi-factor productivity. The authors find an aggregate pooled cross-sectional agglomeration elasticity of 0,171. They also document a considerable variation in the size of estimated industry-specific agglomeration elasticities. In Graham and van Dender (2011) it is argued that for the purpose of transport appraisal it is considered important to have an estimate of total factor productivity (TFP) effects rather than labour productivity alone since it is reasonable to expect changes in accessibility to affect the productivity of both labour and capital. The authors also point out three reasons to be cautious when using the effective density approach. The effect of agglomeration on productivity is endogenous. Endogeneity stems from the misspecification of the link between productivity and agglomeration. Another reason to be cautious is because of the unobserved heterogeneity of different localizations. The heterogeneity can be caused by more highly productive workers and firms being localized in larger agglomerations. There may also be non-linearity problems when estimating effects of a change in effective density. An example is the construction of a new road between places where there has not been a viable link before. A new link will surely cause a big change in effective density which, in turn, implies that the estimates of the elasticity of agglomeration may be incorrect.

In Dehlin et al. (2012) the direct relationship between a measure of effective density and productivity are tested on Norwegian municipality data. The elasticity of productivity with respect to effective density is estimated to be in the interval between 0.0007 and 0.044 depending on functional form. A similar empirical study Hensher et al. (2012) estimates the elasticities to be between 0.007 and 0.168 depending on industry. The across industry average agglomeration elasticity is 0.021. The elasticities of agglomeration in Hensher et al. (2012) are then used as input to a SCGE model, named Sydney General Economic Model (SGEM), in an ex post study of a rail project in Australia. The authors conclude that the total WEI is a 17.6 percent mark-up over conventional benefits of which only 2.46 percent stems from agglomeration.

## Relation to CBA

The traditional method for CBA is based on a partial analysis of the transport markets. This approach gives a full measure of the welfare impacts of a transport investment in the absence of market distortions i.e. assuming markets function according to the assumptions of perfect competition. If the assumption about perfect competition is violated agglomeration externalities may be necessary to account for when calculating the costs and benefits of transport infrastructure projects.

In a general sense today's CBA does not account for agglomeration impacts which both the theoretical and empirical literature has shown to exist. The benefits of a transport infrastructure project are calculated using the transport users' value of time and the change in generalized transport costs. In the value of time the transport users may have accounted for their own increase in productivity but surely they have not accounted for the productivity increase of other workers. This advocates for adding the agglomeration effects to the traditional CBA.

The UK the guidelines for calculation of agglomeration is based on the effective density approach (Department for Transport, 2012). The agglomeration is in this methodology assumed to stem from greater business interaction, more efficient labour market interaction and more efficient input and output markets due to reduced freight costs. These elements are all consistent with the agglomeration literature, but there are two problems which the approach fails to take into account. First the approach does not cover the possibility of negative agglomeration effects in a sufficient manner. Secondly there are large unresolved econometric problems related to the elasticity of productivity with respect to effective density.

Labour market WEI in Sweden is calculated by subtracting time gains from work trips (valued by stated preference) from the Samlok result. This could be seen as a rough estimate, in lack of a theoretically stringent way to relate the results. One should also note that part of the difference comes from the value of time in Swedish recommendations being the same all over the country, while the WEI in Samlok is estimated separately for each region.

## 3.2 Labour supply

Income taxation may give rise to inefficiency in the labour market which has implications when evaluating transport projects. The tax on income causes individuals to make decisions based on their after tax income. On the other hand, the individuals' production value for society is reflected in their wages before tax.

As was the case with the agglomeration benefits, the effects of transport infrastructure are theoretically explained through standard theory which is often partial in nature with some literature on labour supply in an urban equilibrium or SCGE framework.

## **Theory**

The mechanisms behind a change in labour supply as a result of improvements in transport infrastructure are well described in Gibbons and Machin (2006). In the simplest of settings lower transport costs cause increasing employment and lower wages since reduced commuting costs lowers the reservation wages. In addition lower transport costs may increase the size of the labour market pressing the wages down. Lower transportation costs may also change the work hours of existing workers. The change depends on the commuters preferences for work and leisure. Generally in the standard neoclassical labour supply model the labour supply will increase as a result of lower transportation costs and thereby give welfare gains. The authors also point out that this result can be misleading if housing supply is inelastic or labour markets are non-competitive. The labour supply depends on income net of housing costs. If a transport improvement reduces commuting time this may be offset by an increase in housing prices.

Venables (2007) describes how this labour market effect interacts with the productivity increase resulting from increased functional town size (agglomeration). In the model the employees will make their decisions on where to live based on the trade-off that wages are higher in cities (due to agglomeration) and the cost of commuting. The intuition is that there is a tax wedge between the extra income earned by moving to the city, and extra commuting costs of doing so. This is because the commuting costs that are paid out of after tax income. This tax wedge causes (marginal) workers to produce more than their commuting costs would reflect.

Pilegaard and Fosgerau (2008) formulate a SCGE model with labour market search imperfection leading to unemployment. The search imperfections are caused by incomplete information in the labour market. Therefore it takes a while for unemployed workers and jobs to match. In this framework the authors implement a transport improvement and compare the welfare gains against those obtained from a conventional CBA. It should be noted that in the framework of this paper there is no income tax and the main focus of the authors is to show how labour market effects may cause traditional CBA to underestimate the impacts of transport projects. The authors find that additional labour market benefits may be as much as 30 percent in relation to the direct user benefits.

## **Empirical works**

Most of the empirical literature on labour supply is concerned by measuring the elasticity of labour supply with respect to the wage rate. Evers et al. (2005) perform a meta-analysis with a sample of 239 uncompensated labour supply elasticities. One interesting result of the meta-analysis is that the difference between elasticities among countries is small.

When regarding transport infrastructure investment and labour supply, the most important aspect is to examine the causal effect of travel time on labour supply. In the literature the causality is ambiguous. It is both argued that travel time, or commuting time, will decrease or increase the labour supply.

Hymel (2009) examines the impact of traffic congestion on employment growth in large U.S. metropolitan areas. The findings of the analysis indicate that high initial levels of congestion dampen the employment growth. This suggests that reducing urban congestion may lead to substantial urban growth in employment.

Gutiérrez-i-Puigarnau and van Ommeren (2010) analyse the effect of costs of commuting, measured by the commuting distance, on labour supply patterns using the socio-economic panel data for Germany between 1997 and 2007. The results in this study show a small positive effect of commuting distance on labour supply. The positive effect on labour supply is a combination of a positive effect on daily hours and a smaller (negative) effect on number of workdays.

In an analysis of the causal effect of commuting time on labour supply patterns using Spanish data Ignacio Gimenez-Nadal and Molina (2011) find that commuting time increases daily labour supply consistent to the findings in Gutiérrez-i-Puigarnau and van Ommeren (2010).

### **Relation to CBA**

The theoretical results indicate that the existence of income taxes will violate the traditional CBA assumptions thereby causing wider economic impacts. However, part of the value associated with increased labour supply is captured in a traditional CBA analysis of the affected transportation markets. Since the transport users who change their labour supply will make their decisions on the basis of wages after tax resulting from such increased labour supply, this effect will be captured as the change in the consumer surplus of the transport users.

However, the value of the production increase resulting from the expanded labour supply is equal to wages before tax. In order for the entire value of expanded labour supply to be included in the analysis, one needs to add such part of the value of the production increase that is not captured by an traditional CBA analysis. Such additional element corresponds to the difference between the economic value of increasing production by one additional hour of work and the value received by individuals if they work for one additional hour. In practice, such difference is equal to the additional tax revenues resulting from the change in labour supply.

In the empirical literature there exists evidence suggesting commuting time will influence the labour supply. If one assumes that taxes cause an imperfection in the labour market, the traditional CBA methodology should be supplemented by an analysis of increased labour supply.

As with the agglomeration effect, the UK guidelines for calculating wider economic impacts (Department for Transport, 2012) provide a methodology to estimate the effects of transport improvements on labour supply. The additional value added by increased labour supply to the economy and the resulting tax revenue to the government is calculated using a general elasticity of labour supply and generalized transport costs (GTC). There are three possible reasons to be cautious when using this approach. As travel time savings are calculated by the use of a transport model the results are very dependent on the precision of the transport model. The second reason is that the GTC is based on value of time (VOT) from stated preference studies. In such studies it can be unclear whether the respondents have or have not taken the VOT before or after tax. The third

reason is the use of single labour supply elasticity. There may be heterogeneity which calls for an area specific elasticity of labour supply. Examples of heterogeneity can be differences between professions, between areas (spatial heterogeneity) or between industries.

## 4 COMMODITY MARKET

This section discusses how infrastructure improvements can affect the functioning of commodity markets when there is imperfect competition, how it differs from perfect competition, and why the differences are important in the discussion about wider economic impacts. After treating theory, empirics and relation to CBA we treat the case where infrastructure investments are a condition for economic activity.

### Theory

Few commodity markets fulfill the conditions of perfect competition. Several causes of imperfect competition may be related to infrastructure constraints. Accessibility and transportation costs have implications on the size of markets: with weak infrastructure, commodity markets are effectively divided into more local and regional submarkets than in a setting with adequate infrastructure. Table 1 show causes of market imperfections which can be related to transport infrastructure.

**Table 1: Commodity Market Imperfections due to Infrastructure Constraints**

<ol style="list-style-type: none"> <li>1. Weak exploitation of increasing returns to scale</li> <li>2. Immobility of productive factors</li> <li>3. Few buyers and sellers</li> <li>4. Transaction costs in trading between markets (final goods and intermediate goods, respectively)</li> </ol>
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From table 1, two channels can be discerned through which infrastructure impacts the functioning of commodity markets. The first channel concerns points 1 and 2: The *production costs* of firms, and how it affects prices and output. The second concerns 3 and 4: how *competition* between firms works, and how firms position strategically through location, pricing and output. Below follows a theoretical account of the two identified channels through which infrastructure affects the functioning of commodity markets.

#### *Production costs*

A prominent theoretical framework in analyzing trade and imperfect markets is the new economic geography. An important contribution of the new economic geography is that it provides a link between intra-industry trade between nations or regions, and increasing returns to scale (Krugman, 2009). Due to increasing returns to scale, the number of firms producing a good is often limited, since large firms better can exploit scale economies and produce at lower average cost. Consequently, the productivity rate rises as scale economies are exploited. With

larger markets, through improvements in infrastructure, producers face a cheaper and more varied supply of intermediate goods, and a larger potential market to supply with commodities. Furthermore, better accessibility reduces commuting costs of the labour force (through time savings or lower prices), which reduces the wage compensation for commuting which is required to hire necessary labour.

With lower marginal costs of production, standard micro-economic theory tells us that firms will adjust by increasing output, which results in higher welfare. Figures 1 and 2 below give a stylized picture of output and price adjustment in a given commodity market under perfect competition and imperfect competition, respectively. In Figure 1 markets clear where short-run supply (marginal cost of production) meets aggregate demand. When marginal costs of production decreases due to lower transportation costs, prices drop and the quantity produced increases, which increases welfare by the area colored grey. Figure 2 depicts a situation with imperfect competition, where the producer(s) sets output where marginal revenue equals marginal cost. The output level in Figure 2 is below the social optimum. Again, lower transportation costs decrease marginal costs of production, which induce the producer(s) to increase output, increasing welfare by the areas colored grey.

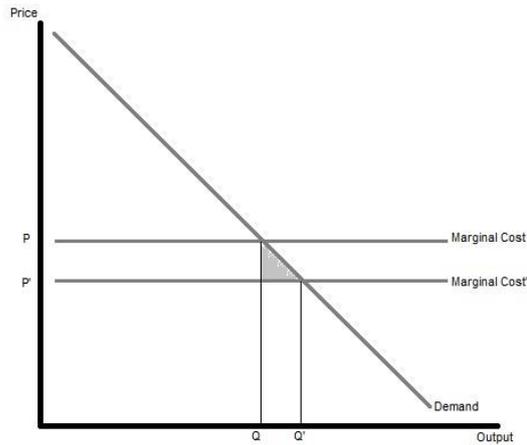


Figure 1: Commodity Market under Perfect Competition

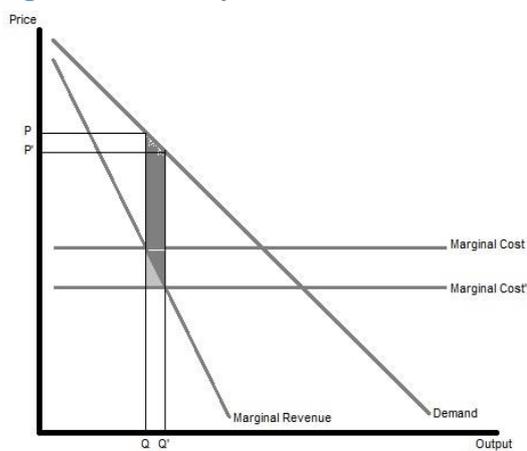


Figure 2: Commodity Market under Imperfect Competition

Importantly, the welfare increase is much larger in imperfect competition. Consequently, the welfare improving effect of infrastructure improvements, in settings with imperfect competition, exceeds the welfare improvements in perfect competition. To sum up, by lowering costs of production, infrastructure improvements can generate welfare benefits by adjusting production levels closer to the social optimum.

### *Competition*

Infrastructure affects the size of local markets, and thus the number of sellers and buyers. All else equal, a small market is more likely to be dominated by one or few sellers or buyers. In a market where firms enjoy market power, the response to lower transport costs through infrastructure improvements will therefore have a strategic component, as the leverage over consumers to exploit market power decreases (Lakshmanan, 2011). When competition is imperfect and sellers have market power, sellers will set prices above the marginal cost of production, and restrict the quantity produced in order to maximize profit. Consumers, on the other hand, are price takers. Ottaviano (2008) shows that product homogeneity and efficiency heterogeneity among firms, in combination with trade barriers, encourage firms to exploit market power in fragmented markets. Lowered trade

costs directly reduces the opportunities to exploit market power, and more so for firms producing homogenous goods. Melitz and Ottaviano (2008) use a model of trade with firm heterogeneity (in productivity) in imperfectly integrated markets to show that larger markets lead to tougher competition, higher overall productivity, and lower price markups.

Aghion and Schankerman (2004) model effects of different competition-enhancing policies using a horizontal product differentiation model where firms are evenly located at a unit circle, unit prices are asymmetric, and firms face transportation costs reflecting physical infrastructure as well as institutional and regulatory constraints. Furthermore, Aghion and Schankerman model entry of new firms using an entry cost function. Consumers are scattered between producers and compare prices between the nearest producers. The model shows that with intensified market competition the market share of low-cost firms increases, price competition is augmented, entry barriers lower, and profit margins are reduced. Simulating their model using real world parameter values for the Herfindahl index of concentration (which measures the level of competition in an industry, defined as the square sum of the market share of the 50 largest firms), average profit margins, entry rates and labour productivity growth, Aghion and Schankerman show that standard cost-benefit analysis understates the welfare gains from competition-increasing policies, such as investment in physical infrastructure. To sum up, infrastructure improvements can generate welfare benefits by augmenting price-competition in commodity markets.

### **Empirical work**

Based on the theory on how infrastructure improvements may mitigate market imperfections in the commodity markets, two empirical questions warrant attention:

- Does lower production costs through improved infrastructure yield welfare benefits in addition to transport cost savings of consumers and producers?
- Does improved infrastructure increase price-competition in the commodity market?

#### *Production Costs*

The empirical question of whether an infrastructure improvement yields lower costs of production is treated in the section about the cost-function approach (section 2.2). The relevant empirical question here is rather whether there are *additional* welfare benefits not captured in the cost-function approach. Unfortunately, there is no empirical literature estimating such additional benefits.

### *Competition*

The competition effect on the commodity markets from investments in physical infrastructure, to the extent that such effects exist, should be subject to highly commodity- and situation-specific settings. The qualitative side of larger commodity markets, in that consumers may select from a wider array of products is hard to quantify. Instead, focus should be on metrics such as mark-up prices and profits.

The empirical literature on the competition effects of infrastructure improvements is scarce. A key reason to the scarcity of empirical estimations is data availability, as measures of competition require firm level data. One industry which has been examined empirically is that of oil products. Pinkse et al. (2002) show that the market for crude oil is global, whereas competition in refined product markets such as gasoline (where price competition decreases dramatically with distance) is highly local. The results on the gasoline market are largely reproduced in Barron et al. (2004) as well as Jimenez and Perdiguero (2010), which indicates that a large number of sellers in an area are associated with tighter price competition.

Another application is Brown and Earle (2001) who use a large panel data set to investigate how physical infrastructure and competition-enhancing policies affected product market dispersion in Russia 1992-1997. The results suggest that there may be indirect benefits from improvements in transportation infrastructure through increased competition, reflected in a lower Herfindahl index of market concentration, as regions with higher density of railroad and highways display higher levels productivity growth. For a given region and industry, well-developed infrastructure enhances the productivity increases of increased market dispersion.

### **Relation to Cost-Benefit Analysis**

Conventional CBA takes into account the cost- and time-saving benefits to consumers and producers of infrastructure improvements. However, conventional CBA does not incorporate the additional effects which may be present when there are market imperfections. Jara-Diaz (1986) analytically shows that different market conditions warrant different forms of welfare analysis. In the British guidelines for WEI calculation, 10 % is added to the welfare gains from lower commuting costs (Department for Transport, 2005). The 10 % is intended to account for the improved function of commodity markets. A paper by The New Zealand Transport Agency (Kernohan & Rognlien, 2011) recommends a 10.7 % uplift factor on business user benefits. The up-factor is calculated, both in the New Zealand Transport Agency paper and the British

WEI guidelines, by relating imperfect competition benefits to business user benefits.

$$\% \text{ of user benefits} = \frac{\text{price cost margin} * \text{aggregate demand elasticity}}{\text{price cost margin} * \text{aggregate demand elasticity} - 1}$$

In the case of the New Zealand Transport Agency, the average price-cost margin is estimated to 20 % and aggregate demand elasticity is -0.6, which gives the following equation:

$$0.107 \approx \frac{0.2 * (-0.6)}{0.2 * (-0.6) - 1}$$

**When infrastructure is a condition for economic activity**

In certain situations, lack of transport infrastructure can be a key obstacle to significant increases in economic activity. For example, isolated locations may have prospects for tourism or mining restrained by insufficient transportation capacity and accessibility. Cost-benefit analysis of infrastructure investments in such situations must include zero, or near-zero tourism or mining activity as the alternative. In such situations, an infrastructure improvement is primarily a condition for economic activity to occur at all, rather than a source of time-savings, environmental improvements, better functioning commodity markets etc. If CBA deems the infrastructure improvements to have long-term net benefits, and the private sector does not find it worthwhile to undertake the necessary infrastructure investments themselves, public initiatives can help overcome the threshold and make possible increases in economic activity which has net benefits to society. In addition to the issue of whether the wider economic benefits of “threshold projects” are considerable, there is a question whether the measured positive effects are organic growth or just a relocation of economic activity. Most studies delimited to regions do not make such distinctions (Chandra & Thompson, 2000). If, for example, a new bridge boosts the tourism and recreation industries of a previously isolated island, it may simply be a reallocation of tourism.

A 2009 study (WSP Analys & Strategi, 2009) of the regional economic effects of infrastructure investments in a peripheral north-Swedish region with prospects of establishing a mining industry, estimated considerable effects on the local economy. The net effects at the national level were also estimated to be positive, not least since the particular region of interest notoriously has displayed low employment levels. A report on transport between the mainland and major islands in the Estonian archipelago (Estonian Road Administration, 2010) provides some experiences of recent major bridge constructions around Europe. While bridges may have considerable local impact on demography and economy,

these impacts are dependent on the proximity of a strong economic center. Moreover, positive effects are typically concentrated to bridgeheads. According to a literature review by Statistics and Research Åland (2009) about the impact of infrastructure improvements on remote regions, the most significant impacts are typically related to the labour market, and not so much the economy at the aggregate level. Also, while significant infrastructure projects increases accessibility in sparsely populated areas, they also tend to enhance centralization of economic activities to the most populated localities. Positive effects on remote areas, however, are enhanced if infrastructure investment is supplemented with private sector investment.

## 5 HOUSING AND LAND MARKETS

This chapter explores the impacts on housing markets and land values brought about by changes in the transport system. The main questions are how investments in transport systems affect property markets and whether these impacts are included in traditional CBA. The section starts out by identifying the relevant markets and gives an overview of different modelling approaches to depict the interaction between transport and land use. Literature presenting evidence of price and land use impacts is reviewed in the empirical part. The section ends with a discussion about the relationship between traditional CBA and the impacts on housing prices and land values.

### **Theory**

Changes in transport infrastructure typically affect accessibility. When accessibility improves, it is expected that prices of residential property increase. One explanation is that commuters respond to transport improvements by moving to an area more distant from their work in search of lower house prices or a better quality of life. As a result, house prices and land values at more distant locations will increase. This will in turn have an impact on construction activity and the supply of housing. Commercial property may also be impacted, but it is not in focus here due to its strong relationship to labour markets. The literary review, therefore, concentrates on housing and non-developed land markets.

In a monocentric city, the relationship between the land values and accessibility can be shown by a bid-rent curve, see the figure below. The bid-rent curve is based on the willingness to pay for land at different distances from the city centre. In central locations with good accessibility, prices on land are high. In the central business district (CBD), offices, restaurants and specific retailing companies are willing to pay the greatest rent. This location is valuable since it is the most accessible location for attracting employment and household demand. Typically, prices decrease with movements further from central locations because of the decrease in competition for land.

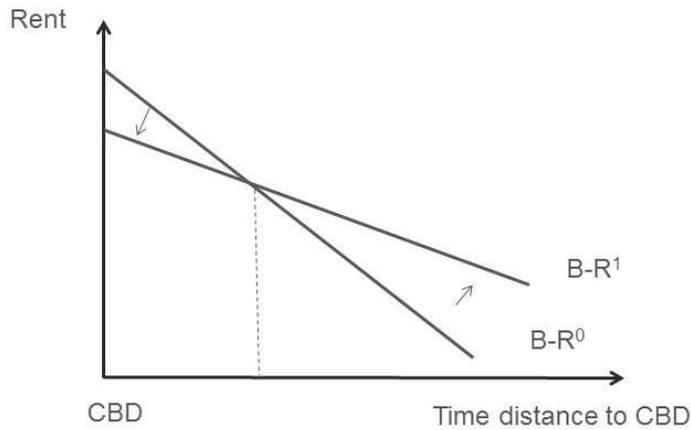


Figure 3: Bid rent curves and the impact of a change in the transport system  
Source: based on Mohring (1961)

New infrastructure that improves accessibility will lead to a pivotal shift of the bid-rent curve from  $B-R^0$  to  $B-R^1$ . It is possible to detect two impacts on prices: higher prices further from the centre and adjustments in the centre of the city as a reaction to lower competition for central locations.

*Land-use transport interaction (LUTI) models*

Land-use transport interaction (LUTI) models try to capture the interaction between transport and land-use. In these models land-use is where people live and work. Changes in transport systems influence how residents and firms choose their location. Simmonds and Feldman (2011) illustrate the markets involved and how the decisions of different actors influence land use, see below figure.

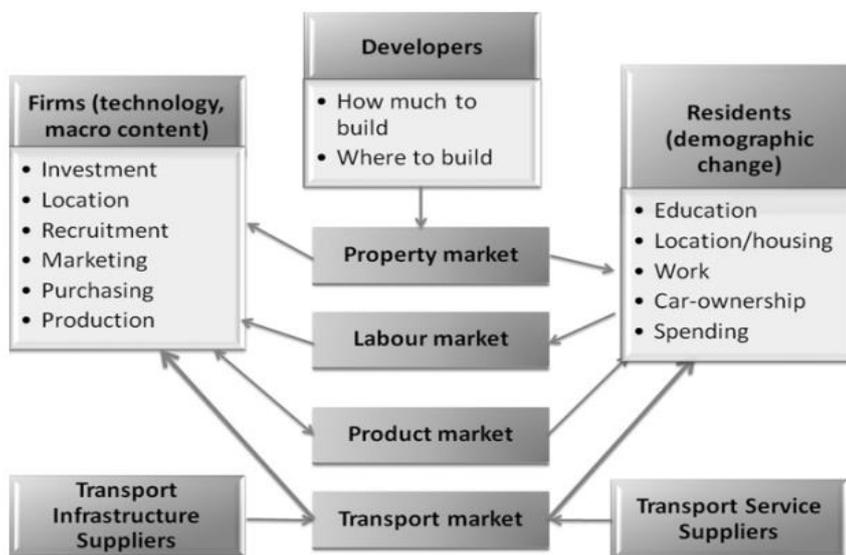


Figure 4: Key decisions by land-use actors Source: Simmonds and Feldman (2011)

The decisions of firms, residents and developers are influenced either directly or indirectly by changes in the transport system. The impacts can be observed either by changes in land use or in prices. The output of LUTI models, show the changes in trip generation and land use. Another feature is that decisions are taken with different frequency. Decisions related to travel are made every day, while e.g. decisions on construction projects are taken much less frequently. In regular transport models, short-term decisions about travel are being modelled, while the more long term decisions on location of employment and households are treated as exogenous. Trafikverket (2011) points out that by this, demand impacts in transport markets will be systematically under-estimated since the long-term impacts of infrastructure investments on land use are not accounted for.

Most land-use transport interaction models rely on random utility or discrete choice theory to explain and forecast the decisions of different actors (Wegener 2004). In their overview of alternative approaches to spatial modelling, Simmonds and Feldman (2011) point out that LUTI models are not homogenous, there is rather a range of different classes of LUTI models. In their classification, they make a distinction between optimising models and predictive models. The purpose of optimising models is to find a design that can optimise some function of the urban system, while predictive models predict the behaviour of urban systems. While the former kinds of models provide a tool for land-use planning, the latter kinds might be seen as an extension of those transport models, which provide input to CBA, e.g. the Swedish Sampers model.

Simmonds and Feldman (2011) further divide the predictive models into: entropy-based models, spatial economics models (spatial input-output models according to the terminology of Batty [2012]) and activity-based (or agent-based) models<sup>1</sup>. According to Simmonds and Feldman (2011), entropy based models rely on statistical mechanics. These models estimate flows between locations according to gravity assumptions proportional to the size and attraction of origins and destinations, and inversely proportional to the travel time and/or cost, (Batty, 2012). The spatial economic or spatial input-output models predict the location of residents, economic activities and flows of goods. Land is considered a non-transportable production factor and its price is determined endogenously, Batty (2012). The agent-based or activity-based models focus on a range of different processes in sub-markets. They rely on microsimulation of land use with the individual (or household, firm, or any other agent in the urban system) as the unit of analysis. Batty (2012) adds one further class of models, the so called sketch-models. These are characterized by

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<sup>1</sup> In addition they make a distinction between static and quasi dynamic models. This is not reported here. Dynamic models differ from the static ones by modelling processes during different points in time.

being simpler, faster, less data intensive and/or less theory rich approaches (e.g. rule-based / GIS-based tools). The table below builds on the scheme developed by Simmonds and Feldman (2011, figure 2) and shows the classification of different LUTI models. In addition, the table includes an attempt to fit the Swedish LUTI models mentioned by Trafikverket (2011) into the scheme.

**Table 2: Selection of land-use transport interaction (LUTI) models**

	Normative models	Predictive models			
	Optimising models	Entropy based	Spatial economic models	Activity-based (agent-based) models	Sketch models
Simmonds & Feldman 2011		LILT DRAM/EMPA L METROPILUS	MEPLAN TRANUS	DELTA URBANSIM	
Trafikverket 2011	LuSIM	IMREL-T/RIM TILT*		URBANSIM LANDSCAPES *	Markov-chain approach

\*Note: Academic models, which have not been used in planning.

The LUTI model LuSIM is a normative optimising (or rule based) model, which allocates additions of residents and employment subject to land-use restrictions and parameter values defined by the user. The model was developed in 2007 by a team at WSP in order to support regional planning tasks of the Stockholm regional plan (Trafikverket 2011). The addition in location is calculated given conditions on densities, zonal restrictions and accessibility. Via a transportation model (LuTRANS or Sampers) it is possible to predict trip generation and mode choice and travel times per zone. The result represents a description of the possible outcomes based on the specific user defined conditions.

One example of a sketch model is the Markov-chain model that has been developed by Anders Hagson to predict the impact of by-passes on commercial location (Trafikverket 2011). Based on data about location of different economic activities from previous by-passes, the authors calculate probabilities of the number of locations during five-year intervals from the opening year. Since the basic assumption is that probabilities are fixed, it remains uncertain, however, how far into future these probabilities can be applied.

Spatial economic models build on some kind of spatial input-output modelling and interaction via transport (Batty, 2012). Production factors are allocated to zones according to zonal production costs (including land prices) and accessibility to zones of consumption. Land prices are determined endogenously through an iterative procedure. Examples mentioned in the

literature include MEPLAN developed by Paul Wadell and his team and TRANUS developed by de la Barra (Batty [2012]; Simmonds and Feldman [2011]; Trafikverket [2011])

Some LUTI models predict transport and activity location separately (MEPLAN and TRANUS), other models (e.g. DELTA developed by David Simmonds and URBANSIM developed by Wadell, IMREL developed by Christer Anderstig and Göran Mattsson) rely on interaction with existing transport models. Several activity-based or agent-based models include the property market, e.g. DELTA, URBANIM and LANDSCAPES, the latter has been developed by Daniel Jonsson (Trafikverket 2011, Wegener 2004). By this they build on microeconomic theory, in particular that of urban land markets and the bid-rent theory.

In entropy models such as IMREL and MEPLAN location is based on accessibility variables, e.g. based on the output of a transportation model. In IMREL both residents and jobs locate according to accessibility to jobs and to employment. In other models, housing costs influence location. The LANDSCAPES model calculates a transport equilibrium, which affects the residential property market and the location of households, while jobs are located according to accessibility of employment (Trafikverket 2011). The approach of e.g. URBANSIM and DELTA goes one step further as employment is located according to equilibrium conditions found by spatial input-output models.

In the article by Simmonds and Feldman (2011), the authors maintain that LUTI models are not alternative to spatial general equilibrium models (SGCE). According to the authors, this is because the SGCE models rather deal with the size of economy and less with location. For instance, they note that SGCE models do not take into account the availability of land and floor-space or labour. They argue that LUTI models such as DELTA has the potential to calculate the WEI defined by the British Department for Transport. The WEI they refer to relate to labour supply and agglomeration impacts.

### **Empirical work**

There are numerous studies, which estimate the empirical impacts of transport infrastructure on house prices. However, Mikelbank (2005) observes that studies on the impact from rail investment are more common than studies of new automobile infrastructure. In a recent study, Efthymiou and Antoniou (2013) estimate the direct impact of different transportation infrastructure on house prices and rents in Athens. They use both Hedonic regression and spatial econometrics. The authors find that proximity to transportation infrastructure can have either positive or negative impact depending on the type of the transportation system. Metro, tram, suburban railway and bus stations affect the prices positively, while heavy rail, airports and ports, have a negative effect.

This is expected to be due to a number of externalities associated with them, such as noise.

Another study that has concentrated on the impact of rail infrastructure finds similar results. Mohammad, et al. (2013) carry out a meta-analysis on the impact of rail projects on land and property values. They use a data set of 102 observations originating from 23 studies covering rail projects in the United States, Europe and Asia originating from the time period 1980-2007. They note that there is a large variety in estimates. Some authors report a negative impact on value from rail investments and others find very little impact. Still the majority of studies report a positive effect. In the literature, negative impacts are found at locations very close to stations or railway lines where noise, pollution and crime levels increase. The authors standardise the changes in land and property values to percentages and report that within their sample the estimated changes in land and property values vary between -45 percent and over 100 percent and with a mean of 8 percent.

The meta-analysis shows that the percentage change in property value is 22-16 percent lower than changes in land values. The authors explain that this difference could be due to land having more potential for varied development than already built properties. In addition, the authors find a stabilisation effect on price increases after announcement, indicating that the perceived benefits of the rail system is higher than the realised benefit. Additionally there is an impact from the type of rail. Commuter rail has about 25 percent larger impact than light rail, while heavy rail has the least impact on prices. Also they find that that the impacts on land and property values are higher in Europe and East Asian cities than in North American cities. The likely explanation is that North American cities are more car-oriented. This explanation is further reinforced by the fact that access to highway reduces the impact on land and property values by about 15 percent. Another interesting finding is that the largest positive impact on land and property values is found at a distance of 500-800 metres from the station, while the impact is 9 percent lower at locations closer to the station.

In a recent article, Knudsen and Rich (2013) make an ex-post cost benefit analysis (CBA) ten years after the opening of the Öresund Bridge. The authors suggest that an ex post CBA has potential to recognise the indirect benefits related to passenger transport due to changes in the choice of location (work and residence). In the article, the authors find that ex-ante traffic models performed reasonably well. However, the main shortcomings were that the forecasts did not account for changes in trip purposes, dynamics during the phasing-in process and the downward price pressure resulting from increased competition. The impact on competition relates to the reductions in crossing prices that occurred as a result of the price competition from ferries. Price

differences in housing markets are handled as determinants of changes in location and, therefore transport flows.

Knudsen and Rich (2013) apply matrixes from the 1999 transport model as a baseline and they use recent counts and surveys to estimate transport flows across Öresund in 2005 and 2010. The ex post transport flows reveal that the pattern of the trip purpose in 2010 was not accurately modelled ex ante. The business and commuting flows are significantly higher than expected due to labour and business relocation (see Knudsen and Rich 2013, Table 17). This is the kind of demand impact Trafikverket (2011) refers to when arguing that impacts in transport markets are systematically under-estimated. Knudsen and Rich (2013) note that the increase in commuting flows was driven by the difference in housing prices and commuters are to a large degree involve Danes moving to Sweden and continuing working in Denmark. Referring back to the chapter on labour market (Chapter 3), this implies that there is no related agglomeration impact for those who move to lower cost houses but do not shift employer.

In the literature, there is discussion about how the scope of the investment will result in larger impacts than just relocation of activities (see e.g. Smit et al. [2013], Trafikanalys [2012]). Small changes in land-use in the proximity of the change in the transport system are expected to be evened out on a national level by redistribution. The pivotal shift the bid-rent curve shown in Figure 3 also gives a hint about possible redistribution effects. At the same time, impacts on house prices seem to occur also when there are incremental improvements in road infrastructure, but they are local and they fade away after a few years (Mikelbank [2004]; Chernobai et al. [2011]). But, on the other hand, large investments or mega projects such as the Channel Tunnel or the Öresund Bridge are expected to bring about a qualitative change. Rather than discussing the scope of the impacts, Knudsen and Rich (2013) suggest some conditions that need to be fulfilled in order to bring about wider economic impacts of major transport links. These are: low exposure to competition from aviation, low degree of border effects and large local labour market agglomeration. In the case of the Öresund bridge there was an impact of competition from ferries, but not aviation. This point is made by the authors based on a comparison with the Channel Tunnel, which mainly serves long distance trips. The low degree of border effects relates to the linguistic similarity between Swedish and Danish.

### **Relation to CBA**

It is important to note that housing and land markets are closely connected to transport markets. This was pointed out more than 50 years ago by Herbert Mohring (1962). He showed that by adding increases in property value to a traditional CBA, there would be double counting. The explanation is that some of the benefits from the transport improvement is captured by the land owners due increases in the demand for land. To count both land value increases and user benefits would be to double count. The basic benefit of the improvement is that which accrues to the users of transport. However, in a literary review on wider economic benefits (COWI 2012) the authors point out that the literature is not decisive about double-counting. Whether wider economic impacts related to property markets can be expected or not, requires separation from those cases with no such impacts. The authors mention that one case implying possible wider economic impacts relates to attraction of local services to residential areas that have gained in accessibility (COWI 2012). This observation and the under-estimation pointed out by Trafikverket (2011), suggest that changes in land use, e.g. attraction of new housing and services might be relevant cases. Still caution needs to be taken in order to separate between redistribution of location and an increase in economic activity.

Those impacts which relate to zonal relocation of jobs and employment have been reviewed in Chapter 3, and the conclusion was that agglomeration adds to productivity. The individual impact is taken into account in the traditional CBA, but the spill-over of productivity increases on other workers is not. In case agglomeration impacts are already taken care of in a CBA, there is a risk of double counting if other relocation is accounted for.

However, the argument, that all effects on land or housing markets are included in the value of time does not mean that they are captured in the traditional CBA. For them to be captured in the CBA requires that all time gains are calculated. Some CBAs focus on effects within the transport mode and assumes that the traffic volumes are not affected by the studied investment or policy measure. This is common for road models, including the Swedish EVA model. To base the CBA on a forecast of future location implies that consumer surplus is calculated also for the traffic not using the road before the investment. Consumer surplus can be found either by using log sums (i.e. integrating under the demand curve) or by applying the rule of the half (i.e. assuming linear demand curves). There is a difference between the change in consumer surplus when future location is accounted for which hinges on the assumption of whether land use is fixed or not, see figure below.

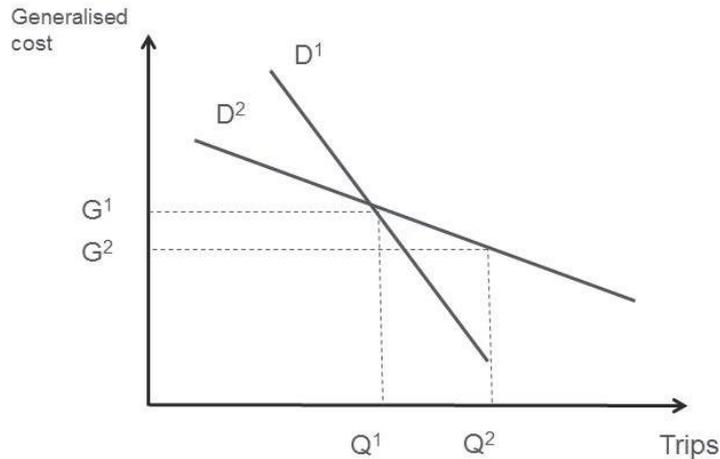


Figure 5: Demand curve D<sup>1</sup> (fixed land-use) and demand curve D<sup>2</sup> (adjusted land-use)

Demand curve D<sup>1</sup> assumes fixed-land use and is inelastic, while demand curve D<sup>2</sup> allows for increased traffic (via adjustments in land-use). Most forecast models include route change, mode change, change of destination and new traffic given fixed location. This means that workers could change jobs due to the investment, but the model assumes that jobs and residence areas are still located in the same places. Most models keep some other parameters fixed as well, the most important is the car fleet, since this is not assumed to be dependent on accessibility, see for example Algiers & Beser (2001). Allowing location to change makes the demand curve more elastic, as shown by demand curve D<sup>2</sup> in the figure above. Allowing for changes in location can be done in two ways, either by estimating land-use and transport demand with a LUTI model or by changing land-use in the transport model exogenously (as in Sampers).

The implications on the effect on total welfare when *not* accounting for changes in land-use depend on the mode of transport. Land-use effects of road investments increases consumer surplus, but also increases external effects (accidents, pollution and noise). The effect on total welfare of omitting land-use effects is ambiguous. Investments in rail infrastructure generally lead to larger land-use effects, and thereby a bigger land-use effect on consumer surplus. Since rail traffic does not suffer from the same magnitude of external effects, the effect of omitting land-use effect is clearly negative (i.e. punishes rail investments).

The effect of redistribution is also closely related to the agglomeration impacts, which increases the risk of double counting effects if both elements are added to a traditional CBA.

## 6 CONCLUSIONS

As we stated in the introduction there are many names used for approximately the same thing. We have focused on “Wider economic impacts” (WEI). WEIs are caused by the existence of market imperfections in transport-using industries, implying that the values individuals place on accessibility changes may differ from those placed on accessibility changes by society. To our knowledge we have treated all WEIs of importance: economic growth, labour market, commodity market, housing market and land market.

### **Economic growth: production function and cost function**

The production function approach explains how inputs like labour, capital, transport investment and other components influence output. The general idea of the production function approach is that if the relationship between increases in transport infrastructure and output is positive and significant, then transport infrastructure is a determinant of output. Meta-studies of the production function approach shows that the average elasticity is between 0.06 and 0.2. Theoretically, if the production function approach includes all relevant effects of transport infrastructure and traditional CBA yields smaller effects of transport investment, then the differences between the production function approach estimates and the CBA estimates should be the wider economic impacts. There is one theoretical problem with the production function approach, namely that it does not include economic behaviour. The empirical literature also finds a wide range of elasticities which should raise suspicion. The reasons for the spread in estimated elasticities is probably that different authors uses different model specification, different time and scope of studies and different data for estimating the elasticities. The uncertainty connected with the estimation of the production function leads us to not recommending it for practical work with wider economic impacts.

Cost function studies have some theoretical advantages over production function studies: allowing for direct estimation on input demand and input substitution elasticities and increasing the statistical degrees of freedom. The ability to derive the marginal benefit of infrastructure, as well as the optimal level of infrastructure, yields a richer analysis than the production approach. Despite the appeal of the cost-function approach, the empirical literature is scarce. A key reason is that the flexibility in econometric specification demands large data sets to be robust

In theory the cost function approach could be used in a similar way as CBA to estimate the effect of an infrastructure investment. If the elasticity of total costs (with respect to transport infrastructure) yields a reduction (i.e. is negative) in

costs when improving transport infrastructure this could be compared with the reduction in GTC in a CBA. In the literature the scope of the estimation of cost functions is more on the macro-scale and offers no evidence of the similarities and dissimilarities of the cost function approach and CBA.

### **Labour market: agglomeration and labour supply**

The consensus in the literature is that urban scale has a positive and significant effect on productivity with agglomeration elasticities typically found to be somewhere between 0.02 and 0.10. Agglomeration caused by improved transport infrastructure can be argued on the basis that the infrastructure increase accessibility of an area thereby making it available for a greater number of workers (and firms). This will increase the economic concentration in the affected areas and may thereby increase the level of agglomeration. There are many theoretical approaches to evaluate how agglomeration causes wider economic impacts. The theoretical works have three main strains. Firstly the spatial general equilibrium approach used in Venables' (2007) influential paper. Secondly the use of spatial computable equilibrium models have received increased attention the later years. Lastly the effective density approach is the theoretical method used most for practical work (Department for transport, 2012).

The benefits of a transport infrastructure projects are calculated using the transport users' value of time and the change in generalized transport costs. In the value of time the transport users may have accounted for their own increase in productivity but surely they have not accounted for the productivity increase of other workers. This advocates for adding the agglomeration effects to the traditional CBA as wider economic impacts. Still there are some theoretical and practical problems with the methods for estimating the agglomeration effects. This leads us to recommend further examination of methods to calculate the effects, but not include agglomeration effects to traditional CBA at this time.

Lower transport costs may cause increasing employment and lower wages since reduced commuting costs lowers the reservation wages. In addition lower transport costs may increase the size of the labour market pressing the wages down. Lower transportation costs may also change the work hours of existing workers. The empirical literature reports a small positive effect of commuting distance (a proxy of transportation costs) on labour supply.

The existence of income taxes will violate the traditional CBA assumptions and may thereby cause wider economic impacts. The additional effect to traditional CBA corresponds to the difference between the economic value of increasing production by one additional hour of work and the value received by individuals if they work for one additional hour. There are, as with the agglomeration

effects, some practical problems when calculating labour supply effects. Firstly the estimated elasticity of labour supply (with respect to travel time) is uncertain and may be influenced by heterogeneity. Secondly there is uncertainty of what the value of time values include since they are based on stated preference studies. Our conclusion is that the labour supply effect is real and should be included as wider economic impacts but there empirical work remains to find accurate elasticities to calculate the effect.

Since labour is an input to production, labour market effects could be translated in to growth effects.

### **Commodity market**

Infrastructure improvements can mitigate imperfections in the commodity market. Theoretically, the main arguments concern welfare benefits, which stem from augmented price-competition and lowered production costs inducing firms to shift output towards the social optimum. Market-improving effects of infrastructure improvements should be largest in transport-intensive industries and where physical infrastructure is under-developed. The empirical literature estimating such effects, however, is scarce. While there is some empirical support for competition-enhancing and cost-decreasing effects in individual markets, it is hard to draw general conclusions. However, to the extent that such effects exist, they are not captured in standard CBA frameworks. The New Zealand recommendations are a 10.7 percent mark-up, while 10 percent is recommended in the UK. The theoretical arguments are convincing and the empirics seem sound. The main problem is that the effects are estimated on macro data, not capturing local / regional differences.

In remote areas, lack of infrastructure can be a threshold to growth. However, when only analyzing regional impacts, there is a question whether potential increases in economic activity unleashed by infrastructure improvements reflects organic growth or just a relocation of economic activity from other regions. This needs to be analyzed from case to case.

### **Housing and land markets**

The literary review demonstrates that transport infrastructure has an impact on prices of land and housing. The empirical studies indicate that transport improvements have a larger impact on the price of undeveloped land than on housing. This could be explained by the fact that undeveloped land has more potential for varied development than already built properties. In addition, literature suggests that there are larger impacts on house prices from rail infrastructure than from road infrastructure.

The changes in prices lead, in turn to changes in land-use. While the implications from price changes are not decisive, the changes that go via changes in land-use

have clear implications on welfare effects. The argument for not including the impacts on property prices in a traditional CBA is that time gains from transport improvements already reflect the change in demand for housing. In most cases this seems to hold. However, the literature also points at some cases when time gains might underestimate the welfare effects of changes in transport systems. One potential WEI is attraction of local services to housing areas that have gained in accessibility. Another case is that traditional transport models, which provide the input to CBA do not account for long-term impacts on land-use. By ignoring these changes in land-use, i.e. relocation and property development implies a smaller consumer surplus. Allowing location to change can correct for this underestimation. This can be done in two ways, either by estimating land-use and transport demand with a LUTI model or by changing land-use in the transport model exogenously (as in Sampers). Since LUTI models account for the market response, the former approach is expected to give greater accuracy when it comes to forecast changes in land-use.

#### **Final remarks on WEI and CBA**

From a policy perspective WEI becomes important when it changes the ranking of the investments. From this perspective localisation effects becomes extra important, since it differs widely in a structural way between different kinds of investment (depends on transport mode, availability of unexploited land etc.). Localisation effects can be included in the CBA, but it is important to remember that price effects (on land and housing) are not captured by these methods. Labour market effect also differs in structural ways, depending mainly on the size of the labour markets affected.

When infrastructure is a condition for (any) economic activity to take place in the area, the circumstances very obviously calls for something else than traditional CBA.

In spite of the methodological issues in estimating different WEIs we have identified, we are of the opinion that the relationship between WEI and CBA is an even more important field and deserves more attention in future research.

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