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The Wider Economic Benefits of Transport Infrastructure: A Review

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TITLE:	**The Wider Economic Benefits of Transport Infrastructure: A Review**
ABSTRACT:	The standard evaluation of transport infrastructure focuses on transport user benefits. Wider economic benefits (WEBs) are claims for additional economic benefits over and above user benefits. This paper reviews five main forms of WEB: agglomeration economies, the value of additional output in imperfectly competitive markets, labour supply effects, induced commercial and residential developments and overall impacts of transport investment on economies. The paper finds that the wider economic benefits in each case are generally likely to be small or non-existent. Where a claim for a substantial WEB is made, it needs to be supported by a reasoned narrative.
KEY WORDS:	***Wider economic benefits, Agglomeration economies, Induced developments***
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The Wider Economic Benefits of Transport Infrastructure: A Review

Peter Abelson

1 Introduction

Many countries spend well over 10 billion Euros a year on transport infrastructure. China, Japan and the US spend many multiples more.[1] In the 2018 Australian budget, the Government stated an intention to invest more than $75 billion in transport infrastructure projects over the next 10 years. Expenditure by the states will likely double that amount. It is especially important therefore that these investment decisions be made efficiently and transparently. It is well known that major transport projects are prone to large cost overruns (Flvbjerg, et al., 2003; Terrill, 2016). In this paper we take up the issue of “wider economic benefits” (WEBs). Whereas the standard cost-benefit analysis (CBA) of transport infrastructure focuses on transport user benefits, WEBs are claimed additional economic benefits.[2]

In a standard CBA, following Mackie et al. (2005) and Cedex (2010), the net social benefit (NSB) or overall welfare outcome of investment in transport infrastructure is given by:

Overall Economic Impact	=	Change in transport user benefits (Consumer Surplus)	+	Change in system operating costs and revenues (Producer Surplus and Government impacts)	+	Change in costs of externalities (Environmental costs, accidents, etc.)	-	Investment costs (including mitigation measures)

To clarify, user benefits are estimated across the whole relevant network (somehow determined), not just on a new mode or route and include existing and new trips. These benefits are principally savings in travel time and vehicle operating costs and often include reliability benefits. Externalities are principally safety and environmental impacts such as air quality and noise. Some externalities may be negative. Further, in cost-benefit studies, in estimates of expenditures, labour is valued at its opportunity cost. This means that, if some of the labour is otherwise unemployed or under-employed, the evaluation implicitly picks up any benefits of the additional employment.

Over time, five principal WEBs have been identified.

1. Agglomeration economies: the impacts of increased employment density on productivity
2. The value of additional output in imperfectly competitive markets
3. Impacts of lower trip costs on labour supply and productivity including additional tax revenue
4. Benefits from induced residential and commercial development, and
5. Overall (macro-economic) impacts of investment in transport infrastructure.

The first three WEBs were identified in the influential seminal paper by the UK Department for Transport (UK DfT, 2005) and have been the focus of most discussion since then. WEBs 4 and 5, induced developments and macro-economic impacts, were discussed as possible benefits in transport literature in the 1980’s and 1990’s. They then largely dropped out of the picture until recently, when

[1] https://stats.oecd.org/Index.aspx?DataSetCode=ITF_INV-MTN_DATA

[2] As some “WEBs” may have negative outcomes, UK DfT (2018a) refers to WEBs as “wider economic impacts”. This paper retains the more common term WEBs.

both impacts have again become live issues. A feature of WEBs is that they are usually associated with some form of market failure.

Estimated WEBs are sometimes large. In the London Cross Rail study, they added over 50% to the estimated standard set of benefits (UK DfT, 2005). In some NZ and Australian projects, they have added 30 to 50% to transport benefits (Douglas and O'Keefe, 2016). In some cases, they may be decisive in producing a positive net present value. But, as we will see, they are often also contentious.[3]

In this paper, Section 2 describes the five WEBs in more detail. For completeness, I also briefly mention there another possible WEB: the potential impact of transport on urban regeneration. Section 3 discusses agglomeration economies (usually the highest valued WEB). Section 4 discusses the other four WEBs. The final section provides conclusions.

2 Five Forms of Wider Economic Benefits

WEB1: Agglomeration economies

Agglomeration economies may be dynamic or static. Dynamic economies occur when productivity (output per worker) rises with greater metropolitan employment. Static economies occur if productivity rises with effective employment density. Effective density rises with lower trip costs between local areas **without** any change in actual employment densities.

Many studies have found that productivity rises with total city employment. In their major survey of agglomeration economies, Rosenthal and Strange (2004) found a doubling of city employment increases productivity by between 3 and 8 per cent. Using meta-analysis, Melo et al. (2009) found an elasticity at the lower end of 0.03. The reasoning is based on scale effects: firms derive productive advantages from greater access to suppliers (reducing the price of inputs), labour (increasing labour productivity) and information (improving technology). Thus, when total employment in an area increases, the output of firms in the area may rise through one or other of these channels. However, as discussed in Section 3, there are various explanations of these differences in productivity. It should be noted that most studies of agglomeration economies were based on *comparisons of metropolitan areas*. Rosenthal and Strange (*ibid*) found little research on localisation economies: where output increases with employment in the relevant industry in the city.

Graham (2005, 2006) and UK DfT (2005) introduced the concept of "effective density". Effective density is a weighted sum of the employment in a designated area and neighbouring areas. The latter has a lower weight as a function either of distance or of generalised trip costs (GTC) between the areas. Using cross-section analysis, Graham (2005, 2006, 2007) found that productivity rises with effective density. Proponents of static agglomeration argue that reductions in GTC increase interactions between areas and that this increases productivity, without any changes in actual

[3] More circumspectly, the UK DfT (2018a, p.1) observed that "modelling and valuing wider economic benefits is complex and subject to a high degree of uncertainty". And as one reviewer of a draft of this paper commented: "increasingly convoluted CBA reports are burying the core results in a mountain of passenger/ benefit multipliers".

employment levels or densities. In practice, reflecting relative ease of modelling, *nearly all applications* of agglomeration economies in transport studies are based on effective density. Box 1 shows UK DFT (2006) advice on how to model these benefits.

Box 1 Estimating agglomeration benefits based on effective densities

UK DfT (2006) proposed that the agglomeration benefit (WEB1) for any area (j) should be based on *changes in estimated effective densities* and calculated as:

$$WEB1_j = GDP_j \times \Delta ED \times EP \qquad (1)$$

where

GDP_j = local economic output in area j

ΔED = percentage change in effective employment density of the area,

EP = the elasticity of total productivity with respect to effective employment density.

Summing agglomeration benefits over all areas and all industries,

$$WEB1 = \Sigma_{ij} [GDP_{ij} \times E_{ij} \times (EIP_{ij} \times \Delta ED_j / ED_j)] \qquad (2)$$

where

GDP_{ij} = GDP per worker in industry i and area j

$E_{i,j}$ = employment in industry i and area j

EIP_{ij} = elasticity of productivity with respect to effective density of industry i in area j

ED_{ij} = effective density of employment of industry i in area j, and

ΔED = change in effective density due to transport project.

Citing Graham (2006), DfT recommended values for EIP_{ij} from 0.04 to 0.11 depending on the industry.

WEB 2 The value of additional output in imperfectly competitive markets

In the standard evaluation approach, the usual assumptions are that markets are competitive and that workers are paid the value of their marginal product. It follows that output arising from business travel time savings should be valued at their relevant wage rate plus any direct overheads such as contributions to superannuation. However, where markets are imperfectly competitive, output prices may be set in excess of marginal cost. This implies that the standard approach undervalues gains in output associated with business travel time savings. This point is generally accepted.[4]

Nevertheless, several questions arise. How extensive are imperfect markets and how great are the mark-ups in these markets? And, critically, do business travellers work while travelling and what is the net gain in output due to savings in business travel time? These points are taken up in Section 4.

WEB3 Impacts on labour supply and productivity

UK DfT (2005) identified three potential labour supply effects due to lower generalised trip costs.

[4] This is essentially a valuation issue for a transport user benefit (travel time savings), rather than an additional economic benefit, but it is treated conventionally as a WEB.

- Working longer hours in current occupations
- Increased participation in the workforce
- Moving to a more productive, higher paid, jobs.

Working longer hours represents a marginal behavioural preference, but no change in trip behaviour. On the other hand, increased workforce participation or moves to a more productive job usually involve new trips. As we will see, each of these benefits is picked up in the standard evaluation approach. The question is whether these valuations are reasonable.

WEB4 Induced commercial or residential development

Induced developments are principally commercial or residential developments that occur as a result of new transport infrastructure that would not occur without it. It has long been claimed, with good reason, that major transport infrastructure may enable development (Adler, 1987). In Australia, development of the major Adani coal mine in Northern Queensland appears to depend on construction of a major rail link. In Sydney, the NSW Department of Transport is claiming major benefits of residential development due to the proposed Sydney West Metro.[5] In such cases, part of the economic surplus of development may be attributed to the infrastructure. As we will see, this usually depends on some form of market failure, notably economies of scale. More complex possibilities arise where firms relocate to take advantage of the new transport infrastructure.

WEB5 Impact of investment in transport infrastructure on the economy

Some experts (Aschauer, 1989; Venables et al., 2014) have suggested that investment in transport infrastructure may have additional economic benefits via investment, jobs or productivity that are not picked up in the standard assessment method. These arguments have also been taken up and analysed at length recently by Ferrari et al. (2019). The principal claim is that output rises with investment and that investment in transport infrastructure increases aggregate demand and create jobs and output. It may also be contended that new transport infrastructure stimulates trade and new firm creation and raises productivity. Thus, this WEB partly duplicates WEBs 3 and 4 and is not regularly included as a separate WEB. On the other hand, the macroeconomic argument is not linked to some market failure and does crop up from time to time. This, the review would be incomplete without some discussion of this possible WEB.

Another cited WEB: the potential impact of transport on urban regeneration

UK DfT (2005) suggested that transport infrastructure could increase competition between markets and thereby change methods of production and increase output which was not accounted for by lower transport costs. The emphasis here was on urban regeneration. However, UK DfT (*ibid*) found few examples of this occurring in the UK. The report concluded that such benefits due to would rarely be significant and that generally no value should be attached to such possible benefits. Subsequently, few claims have been made for this WEB. An exception is Venables et.al. (2014), who found that experience is mixed, with outcomes varying widely across schemes. On the other hand,

[5] The Australian Broadcasting Commission (14 August 2017) reported that the estimated BCR for the proposed metro with standard WEBs was 1.9 and that this rose to about 2.5 with high rise rezoning benefits included.

KPMG (2017) considered that this is unlikely to be a significant WEB in Australia. Given the lack of empirical support for this WEB, this review concurs that this is not likely to be significant at least in countries with extensive established transport networks and urban areas and is not discussed further in this paper. However, the closely related concepts are taken up in the discussion or WEB4.

3 Agglomeration Economies in Transport

The general approach to estimating agglomeration economies is to estimate output per firm (represented by revenue) within an industry as a function of inputs (labour, capital and other purchased inputs) and area employment. This may be represented generally by:

$$\mathrm{Ln}R_{\mathrm{ijn}} = \beta_0 + \beta_1\mathrm{ln}L_{\mathrm{i}} + \beta_2\mathrm{ln}K_i + \beta_3 OPI_i + \beta_4\mathrm{ln}E_{jn} \quad (3)$$

where R_{ijn} = revenue per firm *i* in industry *j* in area *n*, L_{i} and K_{i} are labour and capital inputs employed by firm *i*, OPI_{i} is other purchased inputs, and E_{jn} is employment in industry *j* in area *n*. β_4 represents the estimated % increase in revenue for a 1% increase in employment in the industry (i.e. the elasticity impact of increased employment). Sometimes wages per worker is the dependent variable, for example in Combes et al. (2010) and Hensher et al. (2012). Importantly, employment may be total employment or employment density (employment / size of area). It may also be effective density which includes employment in neighbouring areas discounted for distance or trip costs. The latter approach is common in transport studies, for example Graham (2007), Mare and Graham (2009) and Australian Bureau of Statistics (2017) as well as Combes et al. (2010) and Hensher et al. (2012).

Section 3.1 describes some general issues in agglomeration economies. The rest of the section focuses on the critical concept of effective density, some major empirical studies, and draws conclusions.

3.1 General Issues in Agglomeration Economies

There are several issues regarding estimates of agglomeration economies. First, the size of the geographical units generally reflects political determinations and is arbitrary. A large area may have high total employment but low employment density whereas a small area may have low total employment but high employment density. Theory does not tell us which is more important: employment over a large area or density in a small area.

Second, valuing output, capital and other inputs in dollar terms (not in physical units) creates a problem where prices of outputs vary. Prices are generally higher in large cities where they compensate workers for the higher costs of commuting and congestion (see Glaeser, 2010, and the principle of spatial equilibrium). Also, wages for the same work fall with distance to the CBD (known as the "urban wage gradient").[6] Unless revenues are adjusted for price differentials, estimated productivity differentials are biased. As an example, in Sydney, petrol prices are typically 15% lower

[6] Mills and Cheshire, 1986 (p.1401), "The literature on urban wage gradients finds surprisingly strong support for the hypothesis that wages for otherwise similar jobs decline with distance from the CBD". *Handbook of Regional and Urban Economics*, eds: P. Nijkamp, E. Mills and P. Cheshire.

in outer suburbs than in inner suburbs.[7] But this surely does not mean that petrol station workers are less productive further from the CBD!

Estimating capital inputs is also complicated in absence of ready data sources other than corporate depreciation, which is based on historic costs. And there are often sparse data on intermediate inputs – utility, materials costs etc.

Third, productivity has many causes. Thus, there are "sorting effects": cause and effect must be sorted. The analysis of agglomeration economies often ignores natural competitive advantages. In many countries, cities grew up around ports, government centres and high amenity areas. These centres attract population and have a high demand for labour. As Glaeser (2010, pp.13-14) observed: "Productivity certainly attracts population…the basic problem with estimating agglomeration effects on productivity is that population density is not exogenous. People move to places that are more productive." Likewise, Combes et al. (2010, p.16) observed that "density and measures of productivity (wage or total factor productivity) may be simultaneously determined" by some third factor. More productive workers may sort into denser (high priced) areas. It cannot be assumed that labour is equally skilled in all centres or that all jobs even within an industry sector, such as banking or legal services) are the same across the urban area.[8]

Finally, the relationship between transport and employment needs to be "explicitly modelled" (UK DfT, 2018d, p.10). More employment in one area may be offset by less employment elsewhere, the displacement effect emphasised by UK DfT (*ibid*.). Indeed, transport infrastructure may decentralise employment. Ferrari et al. (2019) cite some international examples of firms relocating regionally in relation to new transport infrastructure, but these examples do not provide for generalisations or substitute for modelling the relationship between transport and employment location in each major context.

3.2 The Concept of Effective Density

Following UK DfT (2005), effective employment in area *j* equals employment in area *j* plus employment in adjacent areas (*k*) as a weighted function of generalised trip costs (GTC) between area *j* and the other areas.

$$ED_j = E_j + \Sigma E_k T^{\alpha}_{jk} \quad (4)$$

where E_j = employment in area j

E_k = employment in neighbouring areas k

T_{jk} = generalised cost of trips between area j and areas k

α = a decay parameter that reflects the lower importance of employment further away.

However, there are many definitions of effective density. Variations include:

[7] See NRMA website: www.fuelcheck.nsw.gov.au/app

[8] It should be noted that Melo et al (2009) claimed that correcting for reverse causality between agglomeration and productivity (using instrumental variables) did not produce a statistical difference in the size of elasticities for urban agglomeration.

- Employment may be total, or industry, employment in an area.
- Density figures may be obtained by dividing employment by size of area.
- Importantly, effective density effects are generally modelled as a function of distance between areas, which is more readily observable than GTC.

There is no theoretical basis for definition of an area or distance decay weighting. The default parameter value for *a* is -1.0, but this may be varied. The higher the value of *a,* the more rapidly agglomeration effects fall with distance. Graham (2006) assumed a value of 1.0. Graham et al. (2009) found that 1.0 was appropriate for some sectors, but that higher decay factors of 1.6 was more appropriate for manufacturing and 1.8 for consumer and business service sectors.

On the other hand, estimated changes in effective density are based on changes in GTC between areas. This may be a weighted metric based on the GTC of various travel modes. Where GTC is intended to reflect costs of business-to-business travel, this should reflect the main business modes and times of travel, principally in off-peak times. Critically, as GTC falls, effective density rises without any changes in actual employment. Indeed, effective density can rise when actual employment density falls.

Is productivity likely to rise with increases in effective density without any changes in employment locations? This question sets up three more questions. Do lower GTC significantly increase business travel between neighbouring employment centres? Generated business trips are an essential input to static economies.[9] How should these new trips be valued? And, would these extra trips create agglomeration economies?

Very few short-distance business trips are made by train or bus; most are made by walking or taxi, often in off-peak hours. (See major study in New Zealand[10]). New transport infrastructure usually reduces door-to-door GTC for such trips only marginally. Studies (Goodwin, 1996; Abelson and Hensher, 2001) have found that generated trips are small in relation to existing trips. Thus, lower GTC generally has little impact on short-distance business trips. Further, generated trips are usually of marginal business importance. Where lower GTC generate new business trips, these are valued in the standard evaluation process by the Rule of a Half as shown in the Annex. Thirdly, a small number of marginal business trips is unlikely to generate significant external agglomeration economies.

We conclude that agglomeration economies associated with generated business trips are likely to be exceptional and small. This is supported by our literature review below.

[9] The Australian Transport and Infrastructure Council (2016, p.6) noted that agglomeration benefits will occur only if there is a significant change in business travel between employment centres "because agglomeration benefits derive from business-to business interaction".

[10] A large survey of bus and train users in Auckland, Christchurch and Wellington found that company business trips were only 1 per cent of total trips. https://www.nzta.govt.nz/assets/resources/research/reports/565/565-Pricing-strategies-for-public-transport-part-1-main-report.pdf.

3.3 Major Studies of Effective Density

Despite the extensive literature on agglomeration economics, there are few empirical studies of the productivity effects of effective density. We make brief comments here on three seminal studies: Graham (2007)[11] in the UK, Graham and Mare (2009) in New Zealand and Combes et al. (2010) for France. We also review two Australian studies: Hensher et. al (2012) and the Australian Bureau of Statistics (2017).

Graham (2007)

Graham estimated the relationship between firm revenue and effective density based on firms within designated industries in 8000 areas (wards) in the UK. Multi-plant firms and firms with more than 100 employees were excluded. Graham regressed firm revenue as a function of labour and capital inputs and effective density based on distance between areas with an assumed value of -1 for the decay factor (α).

Graham reported high agglomeration elasticities, ranging from 0.07 for manufacturing to 0.197 for services, with an average urban elasticity of 0.129. However, after allowing for the heterogeneity (variety) of products or services within each industry, Graham et al (2009) estimated revised, much lower, agglomeration elasticities averaging 0.04 and ranging from 0.02 for manufacturing and consumer services to 0.08 for business services.

Moreover, revenue reflects prices. Thus, some of the estimated impact may reflect higher prices in denser employment areas. Also, Graham measured capital employed by firms in dollars. These monetary estimates are hard to make consistently and accurately and may include price effects.

Graham was aware of most of these issues. Graham (2006) cited the following issues.

- The concept of an area is arbitrary and has no theoretical basis. Agglomeration economies were based originally on the city size. However, there is no agreement about the size of areas for agglomeration analysis. Little research has been done into the effects of employment densities within cities.
- There is no firm basis for the distance decay parameter, the value of (α).
- In many industries, firms are heterogeneous. Thus, density effects may measure other factors such as internal economies of scale.

These points suggest that extrapolation of Graham's results should be done with considerable care.

Mare and Graham (2009)

This study of agglomeration elasticities across urban areas in New Zealand used longitudinal microdata on enterprises. The authors regressed gross revenue of firms against labour, capital and intermediates and effective density measures based on distance.

[11] Graham (2005, 2006 etc) produced several papers. They basically report the one major research study.

At an aggregate urban level, the study (p.7) found a high degree of agglomeration with an overall elasticity of 0.17. However, 70% of this was due to observable differences in regional industry composition. And when differences in industry composition were fully controlled for by including fixed effects, the overall elasticity fell by 90% to 0.0015.

The authors acknowledged (p.11) that "denser areas are more productive, but this may reflect other factors that are positively associated with both density and productivity. It is more difficult to establish that an increase in density would necessarily lead to an increase in productivity". Critically, they stated (p.41) that our "attempts to control for enterprise heterogeneity using the 'within enterprise' specification were beset by problems of attenuation bias and lack of precision."

Combes et al. (2010)

Combes et al. estimated the relationship mean wages and total employment across urban areas in France with a special attempt to deal with the endogenous quantity and quality of labour. Their main results (p.17) were as follows:

- The raw elasticity of mean wages to employment was slightly below 0.05.
- Controlling only for the endogenous quantity of labour bias lowers the estimate to about 0.04.
- Controlling only for the endogenous quality of labour bias yields a lower estimate of 0.033.
- Controlling for both sources of bias produces a coefficient of 0.027
- Allowing for agglomeration economies to spill over the spatial units of boundaries, their "preferred estimate for the elasticity of wages to local density stands at 0.02".

Hensher, Truong, Mulley and Ellison (2012)

This study regressed (in logarithmic form) average wages in 19 industry sectors in 112 travel zones in Sydney against effective employment densities as measured by distances from the other travel zones. They estimated (Table 1, p.8) elasticities of 0.02 for construction and 0.022 for retail trade up to 0.162 for financial and insurance services and 0.205 for utility services, along with a negative elasticity for accommodation and food services. Not surprisingly, the explanatory power of the equations in such a simple analysis was very low – in most cases the R^2 is around 0.2, suggesting significant omitted explanatory variables.

Again, there are several critical issues. A fundamental one was the assumption that the industries are homogeneous across the city, i.e. producing a similar product with similarly qualified workers across the city. This is clearly not the case, for example in banking and other industries where back offices are often located in lower rent locations away from the CBD. The analysis also made no allowance for price variations across the city or the contribution to output of non-labour inputs.

Australian Bureau of Statistics (2017) and KPMG (2017)

The ABS (2017) estimated firm revenue as a function of labour, capital employed (represented by depreciation), intermediate inputs and effective density by industry in the eight Australian capital cities. All values other than effective density were estimated in dollar terms. In effect, all variations in profits over and above a normal return on capital were assumed due to differences in effective density, and not to other factors such as goodwill or intellectual capital. Other issues include: the arbitrary size of the areas, the arbitrary distance decay curve, the treatment of firms located in more than one area, the assumption of homogeneous firms within an industry, the high number of zeros in the data base, and scaling the coefficients in the production function to equal 1.0.

ABS (2017, Table 7) estimated many insignificant and indeed negative agglomeration effects in many industries in all cities, especially in Adelaide, Perth and Canberra.[12] Of 152 estimates of agglomeration in 8 capital cities over 19 industry sectors, ABS found 42% were positive and significant at the 90% confidence level, 38% were positive but not significant and 29% were negative. Notwithstanding these weak results, KPMG (2017, Table 3) recommended positive measures of agglomeration ranging up to 0.17 for 80% of industry sectors in all Australian cities, 20% with zero impacts and no negative economies. These recommendations are extraordinarily hard to reconcile with the analysis.

3.6 Conclusions

There is evidence that productivity rises with total employment in an area. However, productivity variance across locations has several causes including natural differences between areas and the tendency of productive areas to attract more skilled workers. It is also necessary to allow for the variety of services supplied within an industry (e.g. head offices versus branch offices), price variations between areas and differences in capital inputs. Once these factors are allowed for, the average elasticity of output to employment density appears to be in the order of 0.02. This means that doubling employment would increase output per worker by 2 per cent.

Dynamic agglomeration economies: There is no general relationship between transport infrastructure and employment density. Thus, UK DfT (2018d) requires that any suggestion of dynamic agglomeration economies must be supported by a clear narrative on employment density and explicit modelling of land use and employment changes. The Australian Transport and Infrastructure Council (2016, p.6) also concluded that WEBs may be negative and that “it is bad practice to apply a broad percentage up-lift to the results of the traditional appraisal”. This review supports these conclusions.

Static agglomeration economies: There is little evidence that lower GTC without any changes in employment density have a significant impact on productivity. Improved transport infrastructure usually generates relatively few new business-to-business trips. Most such new trips are of marginal business importance and unlikely to generate significant agglomeration economies. As Douglas and O’Keefe (2016, p.12) observed, static agglomeration “is invisible and largely unprovable”.

[12] To try to avoid the endogeneity of density, in supplementary work the ABS regressed estimated total factor productivity as a function of effective density, but this resulted in low levels of explanation (R^2). The ABS also used fixed effects panel data models with 2006 and 2011 data, but this did not produce significant results.

4 Other Wider Economic Benefits

4.1 Value of additional output in imperfectly competitive markets

If markets are competitive, output gained from business travel time savings is appropriately valued at the marginal cost of the time lost to firms, which is the relevant wage rate plus direct overheads. However, where markets are not perfectly competitive, prices are often set above marginal cost. Accordingly, a premium is needed to value the gain in output.

Following a literature review, UK DfT (2005) found that the price mark-up in the UK varied from 0% in competitive industries to 35% in uncompetitive industries and averaged about 20%. KPMG (2017) estimated a similar average price mark up of 19% in Australia. On the other hand, extra output may reduce market prices. Allowing for this, UK DfT (*ibid.*) recommended that business time savings should be uprated by 10%. KPMG (2017) recommended uprate factors for different Australian cities ranging from 5% to 25%. The uprate factor is the product of the price–marginal cost mark-up and the elasticity of demand. The UK uprate factor of 0.1 is a mark-up of 0.2 times an elasticity of 0.5 (ignoring the negative sign). KPMG (2017)'s average city elasticities ranged from 0.3 to 1.13.

However, there are two other significant issues. First, some savings in business travel time may be converted into leisure time, especially by self-employed workers. More substantially, as discussed and researched at length by Hensher (2001), UK Department of Transport (2009), Wardman and Lyons (2015) and Wardman et al. (2015), there is considerable evidence that much business travel time is spent at least semi-productively, especially given the expanding use of digital work instruments.

Accounting for the productive use of business travel time and for some gain in leisure on the one hand, as well as for output values in imperfectly competitive markets on the other hand, the average value of net output gained from business travel time savings could be *below* the average wage of business travellers rather than above it as is commonly assumed (e.g. Transport for NSW, 2018).

4.2 Impacts on Labour Supply and Productivity

Working longer hours

When a worker saves commuting time, the standard assumption is that she has a constant working week and will enjoy a preferred form of leisure to travel. Transport for NSW (2018) recommends that this preference is valued at 40% of the of the seasonally adjusted full time average weekly earnings for Australia, assuming a 38-hour working week.

Alternatively, someone may choose instead to work longer hours, especially part-time workers. If someone has a choice between extra leisure and work, she is assumed to be indifferent at the margin between leisure and work. If she takes on extra work, she gains after-tax wage income but foregoes leisure time. It follows that the value of the travel time saved is independent of whether the worker experiences improved leisure or takes on extra work.

Equivalently, the welfare effect is significantly less than earnings because extra work has an opportunity cost in foregone leisure time. In a competitive market, a person's after-tax wage exactly compensates for loss of marginal leisure. Thus, switching from leisure to work provides only a marginal net benefit to those who switch. However, the increase in output produces additional tax revenue, which is a social benefit, which is not counted in standard transport evaluations.

Increased participation in the workforce

Increased participation may involve taking on full or part-time work instead of leisure. In standard economic appraisals, the value of taking on work is derived from the "rule of a half". Suppose that GTC falls from $30 to $15 per return trip, or over a year from say $60,000 to $30,000. Following the rule of a half principle, the average (welfare) benefit per additional work trip would be $7.50 per day or $15,000 per annum. As DfT (2018c) noted, the benefit cannot exceed the fall in GTC as otherwise the travel time would not have deterred entry to work. The annex provides more explanation of this valuation principle. Again, a tax benefit accrues to Government due to the additional work, which is a WEB.

There is also the issue of the extent of increased participation. In a modern city, most workers have several workplace options. Thus, the number of workers entering the workforce because of lower transport costs between their home and their (new) employment location is likely to be small. DfT (2018c, p.9) suggests a low labour supply elasticity of 0.1. This is derived from the responsiveness of labour supply to various financial incentives. Thus, suppose the average daily wage after tax is $250, GTC falls by $10 per day, and the labour supply elasticity is 0.1. The net wage after transport costs would rise by 0.4 per cent and employment by 0.04 per cent.

Moves to more productive jobs

The valuation principles for moves from low paid jobs to higher paid ones are the same as for entry to work. Unless there are major barriers on access to jobs, the private benefit cannot exceed savings in GTC and the private benefit is approximated by the "rule of a half". The public benefit is the extra tax revenue.

UK DfT (2005) noted that forecasting such employment moves is under-researched. In this case, there is no simple labour supply elasticity to apply to forecast labour supply shifts. Ideally a land use and transport interaction model would be used to forecast employment and residential relocation impacts of the appraised scheme (albeit that forecasts from such models are often subject to a high degree of uncertainty" DfT, 2018a, p. 39). However, at least, the evaluation should provide an explicit explanatory narrative – not some arbitrary black box assumption.

Conclusions

New transport infrastructure may affect labour supply without changes in the locations of businesses which are picked up in WEB4 (induced development). However, the impacts of changes in GTC on labour supply hours require an economic narrative and are likely to be marginal. When labour supply changes, the rule of a half provides a general proxy measure of the private benefits. There would be some additional tax revenue benefit. The latter is an additional economic benefit over standard assumptions for transport evaluation.

4.3 Induced Commercial or Residential Development

Induced commercial development

Ferrari et al. (2019) cite several recent studies indicating substantial firm developments and relocations around major transport infrastructure in Europe, China and India and drawing out cause and effect. And many readers will have observed how transport facilities and warehousing move to new transport infrastructure. Assuming there is a transport effect on firm location and size, the issue arises as to whether savings in transport costs and do pick up all the benefits of the new infrastructure.

If there are no changes in production costs, any new or relocated development reflects transport cost savings. For new trips, the classic rule of a half, described in the Annex, can be applied. As UK DfT (2018b) notes, in perfectly competitive markets, "user benefits will capture the entire welfare effects of a transport investment" including the benefit of induced development which is captured by application of the rule of a half to savings in GTC.

However, scale economies may occur in various ways, especially via gains to trade and access to larger markets. Venables et al. (2014) give an example of a retail development arising from economy of scale in a more populated area and show that the economic surplus is greater than under the rule of a half measure. Alternatively, multi-plant firms may be able to operate with fewer sites. As shown in the Annex, increasing returns to scale may lower average production costs as well as transport costs.

When production costs fall with economies of scale, the sum of transport savings and the rule of a half valuation for new user benefits underestimates the producer surplus achieved. The true benefit is the sum of the savings in production costs and the transport benefits. However, because economies of scale are particular to each situation, there is no simple way to incorporate these savings into a standard economic appraisal. Rather, the estimated production savings and transport benefits need to be explained and justified on a case by case basis.[13]

Induced residential development

To start the discussion, two basic points should be made. First, it is important to distinguish between residential development that occurs (or can occur) independently of transport investment and development that is 'unlocked' by it. Development is a potential benefit of transport investment **only** in the latter case. Second, development may involve broadly constant costs of production or scale economies. Consider first the constant cost scenario. Suppose that user transport costs fall by $5,000 a year and generate capital uplift of $100,000 per housing unit. Where savings are capitalised in this way, it is double counting to count savings in transport user costs and landowner benefits from residential development.

However, user benefits may not capture development benefits where there are market distortions such as zoning restrictions or economies of scale. To claim a development benefit for a transport

[13] This would certainly apply to a suggestion made by one reader that major transport infrastructure could transform an urban area with a new cultural centre or university. Here, a full place-making CBA would be required as market values would not provide the necessary guidance.

project, the project (i) must be a necessary condition for the development or rezoning and (ii) there must be above normal returns to residential development.

Scale economies create net social benefits when dwelling prices exceed all costs of development, including land, land development, any related public infrastructure costs, construction costs, marketing and finance costs. In this case, the net social benefit from new housing (NSB_{NH}) would be:

$$NSB_{NH} = \sum (MP_{NH} - PRIVC - PUBC) \quad (5)$$

where MP_{NH} denotes market prices of new housing and *PRIVC* and *PUBC* denote total private and public costs respectively of housing development.

Note that there is here **no** reference to displaced developments. The implicit assumption displaced development would be marginal development where the benefits, as reflected in market prices, approximately equalled the sum of private and public costs, so that there is no net social gain or loss associated with this displaced development

However, with scale economies, new housing may be purchased by households who do not use the new transport infrastructure and their benefits are not picked up as new user benefits. In this case Equation (5) applies. DfT (2016) recognized such housing benefits but proposed they be included in qualitative terms in the appraisal summary and not in the monetised costs and benefits. This appears to reflect difficulties in quantifying the impact of transport on housing and the need to avoid double counting with new user trip benefits.

Evidently, a WEB may occur when there are non-marginal residential developments reflecting economies of scale. However, these benefits are likely to be the exception and should be carefully and explicitly described and estimated.

4.4 Transport Infrastructure and the Economy

The issue here is whether transport infrastructure has positive impacts on national output that are not captured by either the standard method of evaluation or by another WEB. Aschauer (1989) reported several studies that regressed GDP against levels of infrastructure investment and estimated a return of up to 60% to infrastructure investment. However, early reviews, such as NERA (1999) and SACTRA (1999), found little evidence that transport infrastructure had a special impact on economic output. First, a common factor may explain output and investment. Alternatively, economic growth may drive investment rather than the reverse. Second, the macroeconomic correlations do not have a clear microeconomic basis. SACTRA (1999, pp.7-8) concluded that “direct statistical and case study evidence … of the effects of transport cost changes (on output) is limited… The effects of transport on the economy are subject to strong dependence on specific local circumstances”. In a report for the World Bank, Straub (2008) concluded similarly.

Venables et al. (2014) re-opened the issue of the macro relationships between transport investment, employment and GDP. They found (p.14) that “the literature dos not supply robust answers to many of the key questions”. And Ferrari et al. (2019, pp. 186-190) cite several more recent studies suggesting an elasticity of 0.1 to 0.2, i.e. a 10 per cent increase in public transport investment would raise GDP by between 1 and 2 per cent. However, they noted that transport investment has no greater return on GDP than other forms of public investment. Thus, if the impact exists, it may reflect that most investment expenditure has more impact on GDP than does consumption expenditure.

Venables et al. (2014, Appendix 4.3) also reviewed how CGE modelling of transport investment tends to produce GDP outcomes greater than net CBA benefits although the latter include non-market benefits. However, the authors remarked that it was not clear what assumptions the CGE models made about displacement of other investment or expenditure. It is important that multiplier effects are either switched off in CGE modelling as in partial equilibrium CBA modelling or fully included in the default case of alternative expenditure.

In the US, Weisbrod (2016) described how state-based evaluations often focus on economic impacts, including regional development and freight logistics and supply chain connectivity. He also noted that transport improvements can enhance labour market participation by enticing more workers into the labour market. However, he found little evidence of these effects, except in rural areas with high unemployment and where labour force participation may rise when employment growth occurs

In considering whether there are economic benefits in addition to those generally estimated in standard evaluation studies, two main points should be made. First, the standard transport evaluation approach values labour at its opportunity cost and picks up all the resource cost savings of transport infrastructure (which can be represented as gains in output). Second, it is generally wrong to include second-round benefits of investment via a multiplier effect of first round spending or income gains. An alternative investment of equivalent size will create similar (though not necessarily exactly equal) multiplier effects. It is wrong to find that costs exceed benefits (C > B) and then apply a multiplier to benefits and argue that MB > C, failing to allow for a multiplier to spending foregone. We conclude, consistent with most literature on the subject, that there are no macro-economic benefits of transport investment in addition to those generally estimated in standard evaluation studies.

5 Conclusions

The standard economic appraisal of transport infrastructure includes user benefits but may require marginal adjustments for additional economic benefits (WEBs) in a few cases. Claims of large WEBs are generally unjustified. When WEBs are claimed, an economic narrative and explanation is essential rather than applying "assumption laden black-box formulae as has increasingly been the norm" (Douglas and O'keefe, 2016, p.18).

More detailed conclusions are:

- Small agglomeration benefits may occur with actual increases in employment density. However, it needs to be demonstrated that the transport infrastructure will increase employment density.
- Changes in effective density due to lower transport costs are unlikely to have significant productivity effects without changes in actual employment densities.

- The value of output associated with travel time savings increases with imperfect competition, but this factor is likely to be more than offset by due allowance for productive work during work trips.
- Transport improvements may marginally increase labour supply or moves to more productive jobs. These benefits are captured by the rule of a half assessment in a standard evaluation method. However, there may be some additional benefits (a WEB) from increased tax revenue.
- Transport infrastructure can induce commercial and/or development and produce development surpluses where economies of scale are achieved. However, the link between transport and development, and the lack of non-transport remedies, need to be demonstrated.
- Consistent with most of the literature, when transport investment displaces other investment, there are no additional macro-economic benefits to be included in standard evaluation studies.

An excellent Norwegeian report (Hagen, Chairperson, 2012) reached similar conclusions. This report was further supported by a wide-ranging review of international practice over 24 counties which found low use of most WEBs (Wangsness et al., 2016). Fundamentally, any claims for WEBs should be carefully demonstrated in the context of any proposed new transport infrastructure. It is inappropriate to simply assume that a WEB exists.

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Annex Valuing User Benefits and Increased Output

This annex outlines the basic method for estimating user benefits. The private generalised trip cost (GTC) is the sum of travel time and fares and other out-of-pocket costs, including taxes. The real *social* cost excludes taxes or charges, such as road tolls, that do not reflect use of resources.

Figure A.1 shows the private GTC and the real social cost for a given trip and mode before and after a transport improvement. There are Q_1 existing trips and Q_2 trips after the improvement. Post-improvement trips include trips diverted from other modes or routes and trips generated by the fall in GTC.

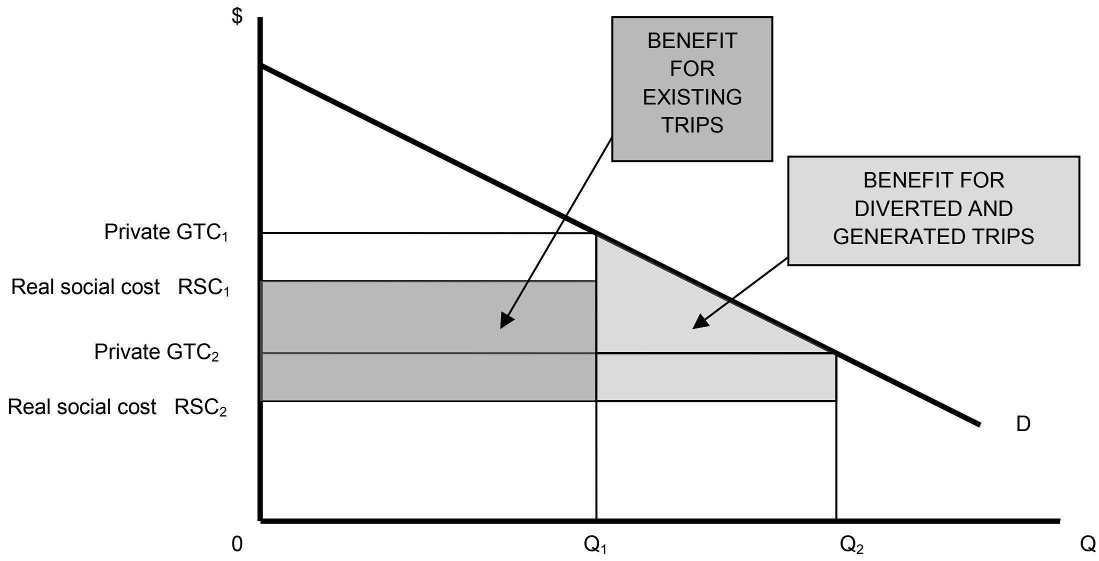

Figure A.1 Benefits of existing, diverted and generated trips

The benefits to existing trips are the savings in real social cost given by shaded area: $Q_1 \times (RSC_1 – RSC_2)$.

Trip makers who divert to a new destination, route or mode are assumed to be willing to pay a price between GTC_1 and GTC_2. If the demand curve is linear, diverted trip makers would be willing to pay an average price of $0.5 (GTC_1 + GTC_2)$. Thus, these benefits are often estimated as $0.5(Q_2 – Q_1) \times (GTC_1 – GTC_2)$. This is known as the “Rule of a Half”. Where $GTC_2 > RSC_2$, there is an additional benefit = $(Q_2 – Q_1) (GTC_2 – RSC_2)$.

The benefits of new (generated) trips are calculated *in the same way* as benefits of diverted trips. The logic is as before. Some new trips would be generated on the improved infrastructure when the cost falls just below GSC_1 but other trips would be generated only when the cost falls close to GSC_2.

This evaluation model also captures the benefits of increased output when firms produce with constant returns to scale. Suppose that a firm sells 1000 widgets at a price of $100 and has the following cost structure (inclusive of transport costs) per widget:

Labour	$ 50
Capital plant and equipment	$ 10
Materials	$ 20
Transport costs	$ 20
Total cost per widget	$100

Now if transport costs fall to $10 per widget, the firm makes a profit of $10 per widget which is the amount allowed for in the evaluation of the *existing* transport of goods.

In addition, firms that previously could produce and transport widgets at between $100 and $110 per widget can now do so at between $90 and $100 per widget and make an average profit of $5.0 per widget sold (assuming no price changes). Thus, some firms may expand output and others may relocate into this market. In each such case, given constant production costs other than transport, the rule of half the savings in transport costs is a realistic measure of the benefit of increased output.

Finally, suppose that there are economies of scale and that, as output increases, other costs fall from $80 to $60 per widget. There are then savings (benefits) of $20 per widget in addition to the direct transport benefits.