Advice on the Assessment of Wider Economic Impacts: a report for HS2

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1. Introduction

This report considers the scope for agglomeration based wider economic impacts (WEIs) in the context of high-speed rail. The current Department for Transport (DfT) methodology for the assessment of agglomeration benefits is based on a theoretical model of the urban economy which essentially emphasises *intra*-urban or regional drivers of productivity. Firms in larger cities are more productive because transactions in input and output markets are rendered more efficient through close proximity to a larger scale of population and economic activity. Applied to the appraisal of transport investments, the underlying assumption is that improved connectivity *within* a city or region will compound the benefits of agglomeration by making the spatial economic transactions even more efficient.

High-speed rail will fundamentally change connectivity *between* cities rather than *within* cities. The key task of this report is to consider whether the agglomeration arguments used to justify the existence of WEIs for *intra*-urban and regional schemes can be extended to inter-regional investments. Essentially, the key questions are: is there reason to believe that high-speed rail investment could give rise to agglomeration benefits, and if so, how substantial might these benefits be?

The key contributions of the report include:

1) **An overview of the theoretical mechanisms that drive agglomeration based WEIs** - we detail the theory of agglomeration economies and consider how the mechanisms underpinning agglomeration may translate over longer (inter-regional) distances. We provide an assessment of whether agglomeration still holds as a useful theory in the context of city to city interactions.

2) **New empirical evidence on long-distance travel** – we provide empirical evidence on labour market and business movements between and within Travel to Work Areas (TTWAs) using data on inter-ward travel flows. We use these data to estimate the nature of distance decay over short and long distances.

3) **An assessment of the potential order of magnitude of agglomeration benefits associated with improvements in long-distance travel** - we develop an empirical approach to sketch out the potential orders of magnitude of agglomeration benefits.

It is important to emphasise that the empirical work undertaken in this report is intended to indicate only general orders of magnitude of wider economic benefits that may arise from
improvements in long distance connectivity. It should certainly not be taken as a definitive or
exact statement on the possible wider benefits of high speed rail. Substantial extensions to
the work presented here would be required to arrive at such estimates. These should be the
subject of future research.

The structure of this report is as follows. Section 2 provides a discussion of the theory of
agglomeration economies and reviews empirical evidence on the magnitude and spatial
scope of agglomeration effects. Section 3 relates the theory of agglomeration to transport
interventions and considers whether the arguments for agglomeration benefits still hold into
the context of high-speed rail. Section 4 presents empirical evidence on the spatial decay of
intra and inter-city commuting and business flows for Britain based on data from the NTM.
Section 5 uses distance decay estimates to indicate potential orders of magnitude of
agglomeration benefits associated with improvements in long-distance travel. Section 6
draws together the main conclusions of the report.
2. Spatial structure of agglomeration economies: theory and empirical evidence

In this section of the report we outline the theoretical foundations underpinning the existence of agglomeration economies and review evidence on the magnitude of these externalities and on their spatial scope.

2.1. Theoretical foundations for productivity benefits from agglomeration

At their broadest level, agglomeration economies occur when individuals benefit from being ‘near’ to other individuals. Nearness can involve physical proximity, but transport and communications play a crucial role because, in most contexts, speed and low costs in transportation and communication provide a direct substitute for physical proximity.

In the text that follows we are specifically concerned with production agglomeration economies, which derive from proximity between firms and the sources of these agglomeration economies: workers, other firms, and other facilities. It is therefore important to understand what mechanisms are likely to drive production-related agglomeration economies, and we start with a brief overview of these issues.

Production agglomeration economies usually mean that the productivity of individual firms rises with the overall amount of activity in other “nearby” firms, or with the number of nearby workers or consumers. That is, agglomeration economies arise because of the production benefits of closer connection with others. The literature traditionally emphasises three sources of agglomeration economies, roughly following three examples given by Marshall (1920): linkages between intermediate and final goods suppliers, labour market interactions, and knowledge spillovers. Input-output linkages occur because savings on transport costs means that firms benefit from locating close to their suppliers and customers. Larger, denser labour markets may, for example, allow for a finer division of labour or provide greater incentives for workers to invest in skills. Finally, knowledge or human capital spillovers arise when spatially concentrated firms or workers are more easily able to learn from one another than if they were spread out over space.

An alternative taxonomy, which sheds more light on the underlying mechanisms, is provided by Duranton and Puga (2004), who classify the sources of agglomeration economies as ‘sharing’, ‘matching’ and ‘learning’. ‘Sharing’ refers to the sharing of indivisible facilities,
intermediate suppliers, workers and consumers by firms, which reduces fixed costs, allows specialisation and allows firms to pool risks. ‘Matching’ benefits are usually discussed in terms the benefits of having lots of workers in close proximity to employers, which means it is easier for different types of worker and different types of employer to find each other, and more productive matches occur at a faster rate. ‘Learning’ refers to the transfer of information, knowledge and skills. Even in a world of fast communication technologies, close connections between large groups of people and firms provide more opportunities for learning and more opportunities for face-to-face contact, which tends to facilitate knowledge exchange and transfer of skills. Both the generation of knowledge and its diffusion benefit from these interactions.

The empirical implementation involved in the estimation of productivity benefits from agglomeration economies has been described by Graham in another report (Graham 2006). Briefly, this involves estimating the statistical relation between the economic output of firms and the degree of agglomeration experienced by the respective firms. This is usually done by fitting a production function in which both private inputs (labour, capital, materials, etc.) and public inputs (e.g. local goods, agglomeration) explain the variation in the level of economic output of firms.

Another common estimation approach uses wage equations. Wage equations can be derived directly from a production function by assuming that factor prices represent the value of the marginal products. Some other researchers use a Mincerian type wage equation (Mincer, 1974) where the wage of worker \( i \) in location \( j \) is explained by a set of worker-specific variables (education, age, etc.) and a set of location-specific characteristics among which is some measure of urban agglomeration economies.

Table 1 shows empirical evidence on the magnitude of agglomeration economies. It lists studies that report elasticities of urban agglomeration economies. The table shows the mean elasticity estimate, the range of estimated elasticity values, the industrial coverage, and the period of the data.
**Table 1: Urban agglomeration elasticities**

<table>
<thead>
<tr>
<th>Study</th>
<th>Journal</th>
<th>Time Period</th>
<th>Economic Sector</th>
<th>Mean</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aberg (1973)</td>
<td>Regional and Urban Economics</td>
<td>1965;1967;1968 1965/1968</td>
<td>Manufacturing</td>
<td>0.017</td>
<td>[0.014;0.019]</td>
</tr>
<tr>
<td>Au and Henderson (2006)</td>
<td>Review of Economic Studies</td>
<td>1997</td>
<td>Economy</td>
<td>0.013</td>
<td>[-0.007;0.033]</td>
</tr>
<tr>
<td>Baldwin et al. (2007)</td>
<td>Economic Analysis research Paper Series</td>
<td>1999</td>
<td>Manufacturing</td>
<td>0.061</td>
<td>[-0.008;0.104]</td>
</tr>
<tr>
<td>Baldwin et al. (2008)</td>
<td>Economic Analysis research Paper Series</td>
<td>1989-1999 (change)</td>
<td>Manufacturing</td>
<td>-0.088</td>
<td>[-0.310;0.300]</td>
</tr>
<tr>
<td>Brulhart and Mathys (2008)</td>
<td>Regional Science and Urban economics</td>
<td>1980-2003 (3 year averages)</td>
<td>Economy;Manufacturing;Services</td>
<td>-0.080</td>
<td>[-0.800;0.280]</td>
</tr>
<tr>
<td>Ciccone (2002)</td>
<td>European Economic Review</td>
<td>1992</td>
<td>Economy (Non-agricultural)</td>
<td>0.047</td>
<td>[0.044;0.051]</td>
</tr>
<tr>
<td>Ciccone and Hall (1996)</td>
<td>American Economic Review</td>
<td>1988</td>
<td>Economy (Non-agricultural)</td>
<td>0.053</td>
<td>[0.035;0.084]</td>
</tr>
<tr>
<td>Cingano and Shividari (2004)</td>
<td>Journal of the European Economic Association</td>
<td>1986-1998 (change)</td>
<td>Manufacturing</td>
<td>0.054</td>
<td>[0.019;0.073]</td>
</tr>
<tr>
<td>Combes et al. (2008a)</td>
<td>Journal of Urban Economics</td>
<td>1976-96 (4 year intervals)</td>
<td>Manufacturing; Services</td>
<td>0.052</td>
<td>[0.024;0.143]</td>
</tr>
<tr>
<td>Combes et al. (2008b)</td>
<td>CEPR discussion paper</td>
<td>1976-96 (4 year intervals)</td>
<td>Manufacturing; Services</td>
<td>0.035</td>
<td>[0.012;0.054]</td>
</tr>
<tr>
<td>Davis and Weinstein (2001)</td>
<td>NBER working paper</td>
<td>1985</td>
<td>Economy (Non-agricultural)</td>
<td>0.027</td>
<td>[0.010;0.057]</td>
</tr>
<tr>
<td>Fingleton (2003)</td>
<td>Oxford Economic Papers</td>
<td>1999;2000</td>
<td>Economy</td>
<td>0.017</td>
<td>[0.016;0.018]</td>
</tr>
<tr>
<td>Fingleton (2006)</td>
<td>Oxford Economic Papers</td>
<td>2000</td>
<td>Economy</td>
<td>0.025</td>
<td>[0.014;0.049]</td>
</tr>
<tr>
<td>Graham (2005)</td>
<td>Working paper</td>
<td>1995-2002</td>
<td>Manufacturing; Services</td>
<td>0.193</td>
<td>[-0.037;0.503]</td>
</tr>
<tr>
<td>Graham (2007a)</td>
<td>Journal of Transport Economics Policy</td>
<td>1995-2002</td>
<td>Manufacturing; Services</td>
<td>0.110</td>
<td>[-0.191;0.382]</td>
</tr>
<tr>
<td>Graham (2007b)</td>
<td>Papers in Regional Science</td>
<td>1995-2002</td>
<td>Manufacturing; Services</td>
<td>0.097</td>
<td>[-0.277;0.491]</td>
</tr>
<tr>
<td>Graham and Kim (2008)</td>
<td>Annals of Regional Science</td>
<td>1995-2002</td>
<td>Manufacturing; Services</td>
<td>0.079</td>
<td>[-0.130;0.306]</td>
</tr>
<tr>
<td>Graham (2007c)</td>
<td>Journal of Urban Economics</td>
<td>1995-2002</td>
<td>Manufacturing; Services</td>
<td>0.194</td>
<td>[0.041;0.399]</td>
</tr>
<tr>
<td>Henderson (1986)</td>
<td>Journal of Urban Economics</td>
<td>1970;1972</td>
<td>Manufacturing</td>
<td>0.010</td>
<td>[-0.366;0.180]</td>
</tr>
<tr>
<td>Henderson (2003)</td>
<td>Journal of Urban Economics</td>
<td>1972-1992</td>
<td>Manufacturing</td>
<td>0.024</td>
<td>[-0.127;0.189]</td>
</tr>
<tr>
<td>Kanemoto et al. (1996)</td>
<td>Journal of the Japanese and International Economies</td>
<td>1985</td>
<td>Economy</td>
<td>0.089</td>
<td>[0.010;0.250]</td>
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<tr>
<td>Lall et al. (2004)</td>
<td>Journal of Development Economics</td>
<td>1991</td>
<td>Manufacturing</td>
<td>0.017</td>
<td>[-0.204;0.658]</td>
</tr>
<tr>
<td>Mion and Naticchioni (2005)</td>
<td>CEPR discussion paper</td>
<td>1991-1998</td>
<td>Economy (Non-agricultural); Manufacturing</td>
<td>0.034</td>
<td>[0.002;0.109]</td>
</tr>
</tbody>
</table>
Table 1: Urban agglomeration elasticities (cont.)

<table>
<thead>
<tr>
<th>Study</th>
<th>Journal</th>
<th>Time Period</th>
<th>Economic Sector</th>
<th>Mean</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moomaw (1981)</td>
<td>The Quarterly Journal of</td>
<td>1967</td>
<td>Manufacturing</td>
<td>0.060</td>
<td>[0.006;0.319]</td>
</tr>
<tr>
<td>Moomaw (1983a)</td>
<td>Regional Science and Urban</td>
<td>1977</td>
<td>Manufacturing</td>
<td>0.038</td>
<td>[-0.052;0.182]</td>
</tr>
<tr>
<td>Moomaw (1985)</td>
<td>Journal of Urban Economics</td>
<td>1967/1977</td>
<td>Manufacturing</td>
<td>0.040</td>
<td>[-0.104;0.270]</td>
</tr>
<tr>
<td>Nakamura (1985)</td>
<td>Journal of Urban Economics</td>
<td>1979</td>
<td>Manufacturing</td>
<td>0.026</td>
<td>[-0.037;0.081]</td>
</tr>
<tr>
<td>Rice et al. (2006)</td>
<td>Regional Science and Urban</td>
<td>1998-2001</td>
<td>Economy</td>
<td>0.025</td>
<td>[-0.005;0.070]</td>
</tr>
<tr>
<td>Nakamura (1985)</td>
<td>Journal of Urban Economics</td>
<td>1980</td>
<td>Manufacturing</td>
<td>0.060</td>
<td>[-0.079;0.300]</td>
</tr>
<tr>
<td>Wheeler (2001)</td>
<td>Journal of Labor Economics</td>
<td>1980</td>
<td>Economy</td>
<td>0.017</td>
<td>[0.000;0.030]</td>
</tr>
</tbody>
</table>

2.2. Transport investments and the spatial scope of agglomeration economies

Transport improvements can increase the strength of production-related agglomeration economies to the extent that these improvements increase the connectivity between firms and workers, between firms and consumers or between firms and other firms. Clearly, some of these mechanisms may be more important than others, and the relative importance is likely to differ across industries and transport schemes. Therefore, it is important to bear these theoretical mechanisms in mind when considering the likely geographical scale over which agglomeration may operate.

These theoretical mechanisms should also guide the choice of factors – workers, other firms, population, facilities etc. – that are included in any measure of ‘agglomeration’, although in practice these factors are closely related to one another and so difficult to disentangle empirically. Reflecting on the mechanisms described above, it is clear that agglomeration economies depend crucially on the flows of goods, people or information between locations. Therefore, the geographical scope of agglomeration economies will depend on the rate at which these flows decrease with distance.

A key issue of importance in understating the spatial scope of agglomeration economies relates to the construction of the agglomeration term itself. This needs to be a variable that represents the potential opportunities for a firm to benefit from the agglomeration economies.
mechanisms in their locality e.g. employment, population or number of firms. Secondly, we need to define what is meant by 'locality'.

The standard set up is to define agglomeration, $A_i$, as an aggregation of workers, firms or population in the geographical neighbourhood of each firm $(i)$. Let us consider employment as an example. Locality is then either defined using predefined statistical or administrative zones, or, more generally, by aggregating employment with higher weights applied to locations close to firm $i$, and lower weights to locations further a-field. This type of agglomeration index has the general structure:

$$A_i = \sum_{j \neq i} a(c_{ij}) z_j$$

(1)

where the weights $a(c_{ij})$ are decreasing in the costs or time $c_{ij}$ incurred in moving between place $i$ and places $j$, and $z_j$ is the variable (e.g. employment) being aggregated to create the agglomeration index. Weights $a(c_{ij})$ are chosen to apply lower weights to locations $j$ that are further away from location $i$. Example weighting schemes include: 'cumulative opportunities' weights $a(c_{ij}) = 1$ if $j$ is within a specified distance of $i$, zero otherwise; exponential weights $a(c_{ij}) = \exp(-\alpha c_{ij})$; logistic weights $a(c_{ij}) = [1 + \exp(-\alpha c_{ij})]^{-1}$ or inverse cost weights $a(c_{ij}) = c_{ij}^{-\alpha}$.

Graham (2006) refers to $A_i$ as effective density, defining $z_j$ as postcode-sector-level employment, setting cost $(c_{ij})$ as the straight line distance between postcode sectors $(d_{ij})$ and imposing an inverse distance weighting system (referred to in the literature as 'gravity-based', after Newton). This means that:

$$a(c_{ij}) = d_{ij}^{-\alpha} \text{ and } A_i = \sum_{j \neq i} d_{ij}^{-\alpha} z_j$$

(2)
Thus, the effective density measure incorporates the two components that capture the amount of agglomeration experienced by a firm located at a site \( i \): the quantity of employment in another location \( j \) (\( z_j \)) and the connectedness of site \( i \) with site \( j \) (\( d_{ij} \)). The parameter \( \alpha \) is assumed greater than zero, such that employment at place \( j \) has less and less potential influence on a firm at site \( i \) as the distance between \( i \) and \( j \) increases. The larger the value \( \alpha \), the more rapidly the potential effect of employment diminishes with distance \( d_{ij} \). For example, if \( \alpha = 1 \), the weight attached to employment decays inversely with distance (employment 10km away from a firm has 1/10th the effect on effective density as employment 1km away). Graham (2006) sets \( \alpha = 1 \).

In the next section we consider the empirical implementation of these ideas in the existing literature.

### 2.3. Empirical evidence on the spatial scope of agglomeration

The market potential measure described above is identical in form to accessibility indices commonly used in transport analysis (e.g. Ahmed and Levinson 2006, Vickerman, Spiekermann and Wegener 1999). Transport accessibility indices typically differ from market and population potential indices in that they measure distance or travel times along existing transport networks, rather than straight line or other distances based purely on relative geographical location. Sometimes, these distances and times are converted into generalised transport costs using estimates of the monetary value of travel time, fuel costs etc. derived from elsewhere - see for example Combes and Lafourcade (2005), Graham (2006).

Accessibility, market potential, population potential or effective density measures based purely on geographical distance create a measure of economic mass at a particular spatial location that depends only on the amount of ‘local’ employment and how far away that employment is. Superficially, it looks as if effective density is only useful for evaluating the effects of interventions that change the number of workers at a given distance, or move workers closer. Whilst useful when thinking about urban housing policy or policy to attract in-migrants, this does not appear directly useful for evaluating the effects of transport improvements. However, distance in this framework is simply a proxy for transport costs or time. Given a fixed set of transport infrastructure and a fixed transport policy regime, a distance of, say 10km, has a corresponding (average) travel time or travel cost. To work from a proposed or actual transport improvement to a change in effective density, we need
only convert the expected reduction in travel times or travel costs in each direction into an equivalent reduction in distance, under the conditions in which the effective density was calculated. For example, if a proposed transport improvement reduces travel costs to the east of site by 20%, then the new effective density at that site will change in way that is equivalent to moving employment to the east 20% closer (i.e. we need to recalculate effective density with distances in the direction of the transport improvement reduced by 20%).

As discussed above, the more direct way to incorporate transport costs or times into estimates of local economic mass is to base these estimates on existing transport costs or times rather than geographic distances. In this case, local employment counts are aggregated up using a penalty that increases with travel costs or times rather than simple distance. It is then easy to see how to convert a policy-induced change in travel costs or time into a change in accessibility. The drawback of this approach and the reason Graham (2006) uses straight line distances in effective density calculations, rather than network distances, times or costs is that the existing transport network and service is in part dependent on transport demand, which is in turn dependent on the level of economic activity and productivity in a given location. There is thus a risk of inferring that closer connection to employment increases productivity, when it is in fact productivity that has encouraged closer connections through development of the existing transport network.

One of the key points emerging from the empirical research on agglomeration economies is the insufficient understanding of the pattern of spatial decay of its effects, both the overall effects and the effects associated with the various mechanisms determining agglomeration. The investigation on the spatial decay of the benefits from spatial concentration is a fairly recent research topic and there are only some papers providing evidence, by and large obtained through indirect measurement approaches that do not obtain an estimate for the distance-decay gradient. These studies use a market potential type function to measure agglomeration, similar to the effective density measure used by Graham. Only a few papers estimate the decay gradient of agglomeration effects (Rice et al., 2006, Amiti and Cameron, 2007, Graham et al., 2009). Graham et al. (2009) is the only study that provides decay rates for various industry sectors.

The next paragraphs summarise the existing empirical evidence on the pattern of spatial decay and scope of agglomeration effects. Overall, the evidence suggests that these effects tend to be stronger within short-distance ranges, beyond which the magnitude of the effects decreases sharply.
Rosenthal and Strange (2008) investigate the spatial reach of agglomeration externalities by regressing US worker wages on the total employment contained within concentric distance rings from workers’ place of work. They find that wages increase by 1.5% to 2.14% for an additional 100,000 full-time workers within 5 miles from the workers’ place of work and fall sharply thereafter: 0.52% (5-25 miles), 0.84% (25-50 miles), and 0.20% (50-100 miles). The elasticity of wages with respect to urbanization is between 0.031 and 0.047: doubling total employment within 5 miles increases wages by 3.1 to 4.7%.

Di Addario and Patacchini (2007) follow Rosenthal and Strange’s approach and estimate that an increase of 100,000 inhabitants within 4 kilometres raises wages by 0.1-0.2% but the increase falls sharply thereafter. The impact of urban size on wages is found to be significant only up to 12 kilometres, which is less than the average radii of Italian local labour markets (14.7 kilometres), and thus suggests that agglomeration economies occur within local labour markets.

There is very little research estimating the distance-decay parameter of agglomeration economies directly. Prominent exceptions are Rice et al. (2006), Amiti and Cameron (2007), and Graham et al. (2009).

Rice et al. (2006) investigate the spatial scope of agglomeration forces by using a measure of economic mass that considers access to population of working age within various driving time intervals. Using an exponential distance-decay function, they estimate the rate of decay to be 1.37 (using an instrumental variables (IV) estimator) and 1.51 (using a nonlinear least squares estimator (NLS)). These values imply that moving the population of working age 30 (60) minutes further away decreases the impact of economic mass on productivity by about 75% (94%) and 78% (95%) respectively.

They also consider the decay of the effect of economic mass on wages. Using an exponential spatial decay function, they estimate a rate of decay of 1.20 for the IV estimation and 1.41 for the NLS estimation, which means that moving the population of working age 30 minutes further away decreases the impact of economic mass on average hourly earnings by 70% (76%), or in other words, that an individual of working age between 60-70 minutes away captures only 24% (30%) of the effects of economic mass on its average hourly wage, compared to an individual of working age within 30-40 minutes of driving time away.
Graham et al. (2009) estimate firm level production functions and obtain a decay gradient (alpha) for Great Britain’s economy of about 1.66 (see table 2 below). The decay gradient of the market potential measure differs across economic sectors; the value is higher for service industries and smaller for manufacturing. Business services and consumer services have a decay gradient of 1.75 and 1.82 respectively, whereas for manufacturing the value is 1.10. This supports a steeper spatial attenuation of agglomeration externalities for the service sectors, which are generally more dependent on urbanisation levels.

Table 2: Summary of empirical results from Graham et al (2009): production function control function specification, non-linear estimation of alpha.

<table>
<thead>
<tr>
<th></th>
<th>agglomeration sic</th>
<th>agglomeration elasticity</th>
<th>alpha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacturing</td>
<td>15-40</td>
<td>0.021</td>
<td>1.097</td>
</tr>
<tr>
<td>Construction</td>
<td>45</td>
<td>0.034</td>
<td>1.562</td>
</tr>
<tr>
<td>Consumer services</td>
<td>50-64</td>
<td>0.024</td>
<td>1.818</td>
</tr>
<tr>
<td>Business services</td>
<td>65-75</td>
<td>0.083</td>
<td>1.746</td>
</tr>
<tr>
<td>Economy (weight aver.)</td>
<td>15-75</td>
<td>0.043</td>
<td>1.655</td>
</tr>
</tbody>
</table>

Whereas the findings from the papers before refer to a “catch-all” type measure of agglomeration economies, Amiti and Cameron (2007) focus on the effects from supplier and market access. They use NLS estimators and find that the distance decay parameter for the supplier and market access, using an exponential form specification, is 1.79 and 2.81 respectively. The findings indicate that only 10% of the benefits of supplier and market access extend beyond 129 and 82 kilometres. The benefits from market access are substantially more localized than those from supplier access, but comparing the distance parameters across years reveals that the market access externality appears to have become less localized over time (fall of the distance decay parameter), whereas the supply access externality appears to have become more localized over time (increase of the distance decay parameter).

There is also evidence from the related discipline investigating the effect of spatial agglomeration on firm birth that seems to agree on a rather localized nature of agglomeration externalities. Rosenthal and Strange (2003) find that the benefits of localization economies (intra-industry employment) on new-establishment births and new-establishment employment are very localized and decline rapidly after the first mile (1.6 kilometres), while more gradually thereafter.
Arzaghi and Henderson (2006) investigate the spatial decay of networking benefits on the birth of advertising agencies in Manhattan. The main result is that networking benefits are highly localised (typically up to 750 meters) and have a peak within 500 meters.¹ An increase of one additional advertising agency within less than 250 meters raises the expected number of births by 2%; one additional agency between 250-500 meters and 500-750 meters results in an increase in the expected number of new firms of 2.3% and 0.4% respectively.² The elasticity of agency births with respect to the stock of advertising agencies up to 750 meters is very high: doubling the stock units raises the expected number of births by 39% (up to 250 meters), 21% (250-500 meters), and 14% (500-750 meters).³ The elasticity of agency births with respect to total agency employment is also high: doubling the employment level raises the expected number of births by 23% (up to 250 meters), 35% (250-500 meters), and 19% (500-750 meters).⁴

2.4. Summary

- Agglomeration economies exist when the spatial concentration of economic activity gives rise to increasing returns in production.

- Theory suggests that the main sources of agglomeration externalities are due to benefits from labour market pooling, knowledge spillovers, and efficiency in input-output linkages.

- Alternatively, we can view the microfoundations of agglomeration in terms of sharing, matching and learning mechanisms.

- Empirical work provides evidence consistent with the existence of agglomeration economies, with estimates of productivity effects lying in the range 1% to 10%.

- Existing evidence generally suggests that the geographic scope of agglomeration externalities is relatively localized, but there is little evidence for the actual rate of decay of agglomeration effects, especially for specific sectors.

¹ Networking effects are measured by the stock of agencies within successive ring distances from the centroid of a census tract.
² Using nonlinear IV-GMM for count data models.
³ Using a Poisson model and a log-linear formulation for the ring counts.
⁴ Using nonlinear IV-GMM for count data models.
Evidence also shows that the geographic scope of agglomeration effects differs depending on which particular source or mechanism is being considered. Studies looking at knowledge spillovers and human capital externalities tend to find small geographic scope, while studies looking at input sharing linkages find effects over larger spatial scales.
3. Agglomeration economies in the context of high-speed rail

Section 2 of the report provided an overview of the theory of agglomeration, detailing why urban economic theory assumes externalities associated with urban scale. From the theory we know that firms do not derive productivity advantages simply because cities are big per se, but because certain activities and processes that generate positive externalities tend on average to be more pronounced in larger cities. Therefore urban scale is advantageous only in so far as it offers a greater level of efficiency in sources or mechanisms that give rise to positive externalities. For example, a large but highly congested city may offer lower returns to city size than a smaller un-congested city due to reductions in the efficiency of the sources of agglomeration.

The key point is that agglomeration is essentially about the scale that can be achieved though proximity. In this sense it is clear that the ease of movement within cities, which is crucial to proximity, clearly counts. We have noted above that transport improvements can increase the strength of production-related agglomeration economies to the extent that these improvements increase the connectivity between firms and workers, between firms and consumers or between firms and other firms. In this section we provide some additional consideration of the relationships between transport and the sources and mechanisms of agglomeration. The objective is to provide an assessment of whether agglomeration still holds as a useful theory in the context of inter-city interactions.

3.1. Transport and the sources and mechanisms of agglomeration

The ease of movement between agents in the economy is a key determinant of access to economic mass, and consequently, has implications for the agglomeration economies enjoyed by firms. In fact, a useful way of thinking about the individual sources of agglomeration, as first proposed by Marshall (1920), is to consider them in relation to transport movements.

i. Labour market pooling - firms derive benefits from ease of access to a pool of skilled workers and specialised professional services. Thick labour markets also permit more productive matches between jobs and workers and induce smaller risks of workers remaining unemployed when firms suffer idiosyncratic shocks. Transport investments can improve labor market based agglomeration benefits by reducing
the costs of labor market interactions, for instance, through improvements in the efficiency of commuting flows.

ii. Knowledge spillovers – the connectivity between firms in part determines the strength of communication and knowledge spillovers. The process of communication and sharing of ideas between firms and workers can enhance firms' and workers' productivity. Transport investments can reduce the cost of firm-to-firm interactions.

iii. Connectivity between firms and costumers (or suppliers) – spatial proximity encourages specialisation in the supply of intermediate inputs, which in turn can lower the average cost of production for firms. Investments in transport can effectively bring a larger scale of activity closer together, potentially allowing the input-output relationships to be conducted with greater efficiency. An important point worth noting is that for service industries in particular, input output associations will involve interactions between workers as well as the exchange of goods.

The classification of mechanisms of agglomeration proposed by Duranton and Puga (2004) can also be used as a basis to consider the relationship between transport investment and sources of agglomeration externalities. Their definition of sharing would be expressed in the demand for non-purpose specific general travel (public goods) but also freight trips (input sharing) and commuting (labour markets). Matching is essentially concerned with labour markets and so would be mostly manifest in commuting trips. Learning comprises inter-firm interactions and so would involve work based business to business trips. Again, we can hypothesise that improvements in the efficiency of these trips, through for example cost reductions, will compound the benefits of agglomeration from each mechanism.

3.2. The agglomeration effects of transport investments: existing DfT approach

In general, then, there are good reasons to believe that transport investments can impact on the microfoundations of agglomeration, generating external benefits that are currently believed to be extraneous under the conventional approach to appraisal. However, the relative importance of each sources or mechanisms is likely to differ according to the type of transport improvement made. Furthermore, the sources and mechanisms discussed above may not provide a comprehensive account of the microfoundations of agglomeration.
externalities. There are other factors, for instance gains from variety and specialisation, for which it is more difficult to propose clear links with transport movements.

The existing DfT WEIs approach does not distinguish distinct effects of transport investments on sources, and indeed makes no mention of mechanisms or sources. Instead, it assumes that a change in access to economic mass achieved through a transport improvement is essentially the same as a proportional shift in the sources or mechanisms of agglomeration economies that are captured within estimated agglomeration elasticities. There is no intermediate stage which attempts to understand the relationship between transport accessibility and sources of agglomeration. The assumption that transport investments will impact on the microfoundations of agglomeration across the board has no empirical basis, and is used only to provide an approximation for appraisal purposes. The extent to which the existing approach provides a reasonable approximation is unknown, but given the discussion above it is hard to imagine it will prove consistently reliable across a diverse range of investments.

The DfT use the concept of Functional Urban Regions (FURs) to provide guidance on where to look for agglomeration benefits from transport schemes; in other words, their spatial scope (see figure 1 below).
The current appraisal of WEIs is essentially concerned with external productivity benefits that can be experienced within a certain radii as defined by the FURs. However, it is recognised that the geographic scope over which these benefits are available can diminish, even within the local economy where the scheme takes place. Some recent research by Graham et al. (2009) shows that the decay of agglomeration differs across economic sectors; the value is higher for service industries and smaller for manufacturing. Business services and consumer services have a decay gradient of 1.8, whereas for manufacturing the value is 1.1 and 1.6 for construction. This supports a steeper spatial attenuation of agglomeration externalities for the service sectors, which are generally more dependent on urbanisation levels. The average value of the distance decay gradient for the whole economy is about 1.66.

An important point to note here is that these spatial decay parameters used by the DfT are based on distance, not travel times or generalised costs.

3.3. Considerations in the context of high-speed rail

In the case of high-speed rail, most of the arguments linking transport to agglomeration could hold in the sense that if spatial interactions between economic agents are made more efficient we may expect increasing returns. There are no obvious characteristics of the sources or mechanisms described in the agglomeration literature that would limit their generation over longer distances. Labour market effects, knowledge spillovers, and worker input-output interactions could each, in theory, be extended through improvements in temporal accessibility over inter-regional distances. Since the existing DfT approach is silent on the sources of these increasing returns there is no particular reason to emphasise them in the context of high-speed rail.

The distance decay parameters used in the DfT calculations may not be appropriate for assessment in the context of high-speed rail or inter regional investments. These values were derived for the appraisal on intra-regional investments and in fact ignore the influence of agglomeration effects beyond 75 kilometre radius.

The extent to which agglomeration economies could be generated through inter-regional movements can be investigated further by looking at the existing nature of such movements and how they might respond to changes in travel times. In the next section we provide some empirical evidence on the nature of commuting and business trips between and within TTWAs in Britain.
3.4. Summary

- There are good reasons to believe that transport investments can impact on the microfoundations of agglomeration.

- The existing DfT approach to the assessment of agglomeration benefits from transport does not consider sources explicitly. Instead, it assumes that a change in access to economic mass is equivalent to a change in the sources of agglomeration (as captured by the agglomeration elasticities).

- WEIs are evaluated for FURs which are a type of city-region definition. Within FURs agglomeration economies decay with distance from source.

- The decay parameters used by the DfT are based on distances, not travel times or generalised costs.

- There are no obvious characteristics of the sources or mechanisms of agglomeration discussed in the literature that would limit their generation over longer distances.

- Thus, most of the arguments linking transport to agglomeration could hold in long-distance case in the sense that if spatial interactions between economic agents are made more efficient we may expect increasing returns.

- The distance decay parameters used in the DfT calculations may not be appropriate for assessment in the context of high-speed rail or inter regional investments.
4. Empirical evidence on long-distance travel

4.1. Introduction

In the previous section we considered relationships between the main determinants of agglomeration economies and different types of transport movement. We argued that the line of reasoning linking transport to agglomeration should hold in the case of high speed rail in the sense that if spatial interactions between economic agents are made more efficient we would expect increasing returns.

In this section we analyse data for Britain to provide evidence on the spatial decay of commuting and business trips (both home-based and non-home-based). The distance-decay gradient of these types of movements can be used to infer potential effects of transport investments such as HS2, and ultimately, about the potential order of magnitude of agglomeration benefits.

4.2. Spatial scope of commuting interactions

In this section we look at the spatial distribution of commuting trips across TTWAs for Britain. TTWAs are the best available approximations of self-contained labour markets; they are defined as regions where the proportion of people who live (work) in the area is at least 75% of the total number of people who work (live) in the area.\(^5\)

Labour market areas are well suited to capture the geographic scope within which agglomeration externalities take place, in particular those related to labour market pooling and knowledge spillovers. On the other hand, these boundaries are less appropriated to capture the spatial reach of the agglomeration effects arising from intermediate input-output linkages between firms which presumably take place between different labour market areas.

If a considerable volume of commuting occurs beyond TTWAs boundaries then this indicates that labour market pooling effects can extend across labour markets. To get an idea about the size of inter-TTWAs interactions we computed the proportion of inter-TTWAs commuting for each TTWAs in Great Britain using commuting flow data from the NTM.

\(^5\) Similar geographic definitions can be found in the literature measuring the productivity benefits from agglomeration, including the French employment areas (e.g. Combes et al., 2008a, Combes et al., 2007, Combes et al., 2008b) and the Italian local labour markets (e.g. Blasio and Di Addario, 2005, Di Addario and Patacchini, 2007), both defined on the basis of daily commuting patterns. We use TTWA as at 1998. For the list of names and codes see: http://www.statistics.gov.uk/geography/geographic_area_listings/other.asp.
From figure 2 we observe that the proportion of inter-TTWAs commuting differs across TTWAs and can reach considerably high shares. Figure 2 is the histogram of the proportion of inter-TTWAs commuting. The values shown in the X-axis are the values of the proportion of outside-TTWAs commuting and the values in the Y-axis are the number of TTWAs. The mean value for the proportion of outside TTWAs commuting is about 25%, which is just about the same value as the 25% threshold used in the creation of the borders of the TTWAs. But there are values above this threshold that can be as high as 70%. This suggests that there is considerable commuting between different TTWAs although the extent differs across the TTWAs.

Figure 2: Proportion of inter-TTWAs HBW flows
Source: authors own calculations.

To estimate the distance-decay gradient of commuting trips we use data from the NTM, which covers the whole of Great Britain. We use data for the flows of home-based work trips (HBW) at the PASS3 zone level. To measure the ‘mass’ of the origins and destinations we use population and employment variables respectively. To represent the spatial distance

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6 Although the Annual Survey of Hours and Earnings (ASHE) could also be used to fit gravity models using data on observed commuting flows, there are insufficient observations to perform regression analysis on some TTWAs in Scotland. We therefore use the flow data in the NTM to estimate distance-decay gradients for commuting flows.

7 PASS 3 zones are aggregations of CAS wards in 9,998 zones.
between each pair of PASS3 zones we compute Euclidean distances. In addition, we associate the TTWAs to the PASS3 zones in order to distinguish between intra- and inter-labour markets interactions. The general model to be estimated can be written as shown below:

\[ \log F_{ij} = c + \beta_1 \log M_i + \beta_2 \log M_j + \alpha d_{ij} + D_i + D_j + e_{ij} \] (3)

Where \( F_{ij} \) are the commuting flows between PASS3 zone pairs, \( M_i \) (population), \( M_j \) (employment), and \( d_{ij} \) are the mass of origin PASS3 zone, the mass of destination of PASS3 zone and the distance (in kilometres) between the two areas respectively. To control for potential heterogeneity across origins and destinations we further include a set of control variables based on the FORGE rural-urban classification for PASS3 origins \((D_i)\) and PASS3 destinations \((D_j)\). Finally, \( e_{ij} \) is the residual term and is assumed i.i.d. normal.

We estimate the gravity models for all flows, intra-TTWAs flows, and inter-TTWAs flows using an OLS estimator with origin and destination specific controls at the FORGE level. The results obtained are reported in table 3 below. The estimates for the distance gradient suggest that for all commuting trips an increase in distance of one kilometre produces a reduction in commuting flows of about 5.5%. Using data on long-distance flows only, the decay gradient suggests a reduction in commuting flows of 3.9% for one additional kilometre. For commuting trips inside the same labour market commuting trips increasing journey to work by one kilometre leads to a fall in flows of 1.7%.

This suggests that commuters may be less sensitive to increases in commute length inside labour markets than increase in the length of commutes that cross different labour markets. Intuitively, this makes sense since urban transport services inside labour markets are more frequent and better coordinated than between different labour markets.

The estimates for the mass of origin and destination PASS3 zones indicate positive impacts on commuting flows: the larger the origin (destination) the more commuting flows between the two zones.
### Table 3: Gravity models for commuting flows

<table>
<thead>
<tr>
<th></th>
<th>HBW</th>
<th>Inter HBW</th>
<th>Intra HBW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Log of population in origin</td>
<td>1.9502</td>
<td>2.1422</td>
<td>0.9706</td>
</tr>
<tr>
<td>Log of employment in destination</td>
<td>1.6842</td>
<td>1.7597</td>
<td>1.4179</td>
</tr>
<tr>
<td>Distance (km)</td>
<td>-0.0550</td>
<td>-0.0394</td>
<td>-0.0168</td>
</tr>
<tr>
<td>Observations</td>
<td>2,101,610</td>
<td>1,659,416</td>
<td>442,194</td>
</tr>
<tr>
<td>R2</td>
<td>0.20</td>
<td>0.13</td>
<td>0.21</td>
</tr>
<tr>
<td>Adj. R2</td>
<td>0.20</td>
<td>0.13</td>
<td>0.21</td>
</tr>
</tbody>
</table>

Legend: *** p<.01

### 4.3. Spatial scope of business interactions

In this section we present the results for the distance-decay gradient of home-based and non-home-based employer business trips. We use data for the flows of home-based employer business trips (HBEB) and non home-based employer business trips (NHBEB) at the PASS3 zone level.

To get an idea about the size of inter-TTWAs interactions for these trips we computed the proportion of inter-TTWAs flows for each TTWAs in Great Britain using commuting flow data from the NTM. From figure 3 (HBEB flows) we observe that the proportion of inter-TTWAs commuting differs across TTWAs and can reach considerably high shares. The mean value for the proportion of outside TTWAs commuting is about 50%, which is higher than the 25% threshold used in the creation of the borders of the TTWAs. Concerning NHBEB flows in figure 4, the mean value for the proportion of outside TTWAs commuting is about 45%.
Figure 3: Proportion of inter-TTWAs HEBEB flows
Source: authors own calculations.

Figure 4: Proportion of inter-TTWAs NHEEB flows
Source: authors own calculations.
The general model to be estimated can be written as in equation (3) above, repeated below for simplicity:

\[
\log F_{ij} = c + \beta_1 \log M_i + \beta_2 \log M_j + \alpha d_{ij} + D_i + D_j + e_{ij} \tag{4}
\]

Where \( F_{ij} \) are the business flows between PASS3 zone pairs, \( M_i, M_j \), and \( d_{ij} \) are the mass of origin PASS3 zone, the mass of destination of PASS3 zone and the distance (in kilometres) between the two areas respectively. Again, to control for potential heterogeneity across origins and destinations we further include a set of control variables based on the FORGE rural-urban classification for PASS3 origins \((D_i)\) and PASS3 destinations \((D_j)\). Finally, \( e_{ij} \) is the residual term and is assumed to i.i.d. normal.

We estimate the gravity models both for home-based employer business flows (HBE) and for non-home-based employer business (NHEB) flows. In addition, separate models are estimated for all flows, intra-TTWAs flows, and inter-TTWAs flows using OLS with controls at the FORGE level. The results obtained for the HBE and NHEB are reported in table 4 and table 5 below respectively.

The estimates for the distance gradient suggest that for all HBE trips an increase in distance of one kilometre produces a reduction in flows of about 0.61%. If the model uses data on long-distance flows only, the decay gradient indicates a reduction in flows of 0.4% for one additional kilometre. For HBE trips inside the same labour market an increase of one kilometre leads to a fall in flows of 0.55%.

The results for the distance decay gradient of NHEB flows are very similar to the values obtained for the HBE flows. The estimates for the distance gradient suggest that for all NHEB flows an increase in distance of one kilometre produces a reduction in flows of about 0.61%. If the model uses data on long-distance flows only, the decay gradient suggests a reduction in flows of 0.35% for one additional kilometre. For trips inside the same labour market an increase of one kilometre leads to a fall in flows of 0.53%.
Table 4: Gravity models for home-based employer business flows

<table>
<thead>
<tr>
<th></th>
<th>HEBEB</th>
<th>Inter HEBEB</th>
<th>Intra HEBEB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Log of population in origin</td>
<td>1.9481</td>
<td>2.0425 ***</td>
<td>0.9772 ***</td>
</tr>
<tr>
<td>Log of employment in destination</td>
<td>3.8619</td>
<td>3.9394 ***</td>
<td>3.3708 ***</td>
</tr>
<tr>
<td>Distance (km)</td>
<td>-0.0061 ***</td>
<td>-0.0040 ***</td>
<td>-0.0055 ***</td>
</tr>
<tr>
<td>Observations</td>
<td>4,598,922</td>
<td>4,055,990</td>
<td>542,932</td>
</tr>
<tr>
<td>R2</td>
<td>0.20</td>
<td>0.19</td>
<td>0.19</td>
</tr>
<tr>
<td>Adj. R2</td>
<td>0.20</td>
<td>0.19</td>
<td>0.19</td>
</tr>
<tr>
<td>Controls</td>
<td>FORGE origin</td>
<td>13,761.84 ***</td>
<td>13,198.36 ***</td>
</tr>
<tr>
<td></td>
<td>FORGE destination</td>
<td>6,411.85 ***</td>
<td>4,784.37 ***</td>
</tr>
<tr>
<td>Legend: *** p&lt;.01</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 5: Gravity models for non-home-based employer business flows

<table>
<thead>
<tr>
<th></th>
<th>NHBEB</th>
<th>Inter NHBEB</th>
<th>Intra NHBEB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Log of total mass of origin</td>
<td>1.1383</td>
<td>1.3225 ***</td>
<td>0.3686 ***</td>
</tr>
<tr>
<td>Log of total mass of destination</td>
<td>3.1453</td>
<td>3.3374 ***</td>
<td>2.3092 ***</td>
</tr>
<tr>
<td>Distance (km)</td>
<td>-0.0061 ***</td>
<td>-0.0035 ***</td>
<td>-0.0053 ***</td>
</tr>
<tr>
<td>Observations</td>
<td>5,067,281</td>
<td>4,465,602</td>
<td>601,679</td>
</tr>
<tr>
<td>R2</td>
<td>0.16</td>
<td>0.16</td>
<td>0.09</td>
</tr>
<tr>
<td>Adj. R2</td>
<td>0.16</td>
<td>0.16</td>
<td>0.09</td>
</tr>
<tr>
<td>Controls</td>
<td>FORGE origin</td>
<td>5,800.73 ***</td>
<td>7,158.03 ***</td>
</tr>
<tr>
<td></td>
<td>FORGE destination</td>
<td>11,128.21 ***</td>
<td>9,620.28 ***</td>
</tr>
<tr>
<td>Legend: *** p&lt;.01</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4.4. Summary

- The distance-decay decay gradient of commuting trips (connecting firms and workers) and business trips (connecting workers) can be used to infer potential effects of transport investments such as HS2.

- Evidence on the spatial distribution of commuting flows shows that there is considerable long distance interaction between Travel-to-Work Areas. The proportion of inter-TTWAs commuting flows can be as high as 70%.

- Evidence on the spatial distribution of business flows also shows considerable long distance interactions between TTWAs. The proportion of inter-TTWAs home-based and non-home based business flows can be as high as 87%.
• The high proportions of long-distance flows suggest that high-speed rail could have an important effect on the level of connectivity between firms (business movements) and the level of connectivity between workers (commuting movements).

• To obtain the distance decay gradient of commuting and business movements respectively, gravity models are estimated using data on commuting flows and business flows from the NTM.

• The estimates for the distance decay gradients indicate that commuting flows are more responsive to changes in distances. An increase of one kilometre in commute lengths produces a reduction in long-distance HBW flows of about 3.9%. An increase of one kilometre in business distances produces a reduction in long-distance HEBB and NHBEB flows of about 0.4% and 0.35% respectively.
5. Potential order of magnitude of agglomeration benefits

5.1. Introduction

Using the empirical estimates presented in section 4 we can provide some indications of the potential orders of magnitude of agglomeration benefits associated with improvements in long-distance travel. It is important to stress at the outset that these are not to be taken as estimates of the likely agglomeration effects of high-speed rail. We have not had the time or data to make calculations that could approximate any such effect.

That said, the calculations we present here, although based on some arbitrary values, do offer an approach for the measurement of long-distance agglomeration benefits that could usefully be developed further. In particular, our approach addresses the issue of distance versus temporal decay which is particularly important in the context of long-distance and high-speed investments. The current DfT approach to the assessment of agglomeration benefits allows agglomeration effects to decay spatially, but the decay effect is assumed constant and is relevant only with respect to distance. Our approach uses the econometric evidence presented in section 4, along with some assumed parameter values (taken from published transport statistics), to allow constancy of decay with respect to equal average travel times but variability with respect to distance. In other words, we allow two equal distances to have different decay profiles if travel times vary, but the decay is always the same for equal travel times. This causes the distance decay parameter to change following a transport investment.

As mentioned above, the existing DfT approach makes no mention of sources but instead looks at how ‘effective densities’ change in aggregate and assumes that such changes translate directly into shifts in ‘agglomeration’. Another potentially beneficial aspect of our approach lies in the use of decay estimates for different trip purposes rather than aggregate density changes. This approach could be developed further to improve our understanding of the links between transport movements and potential sources of agglomeration.

5.2. Methodology

The key assumption underpinning our approach is that travel times, not distance, are the dominant factor underlying perceptions of the attenuation factor for any zone. To represent the relationship between interactions and travel time, we use the following expression:
\[
\frac{d \log F}{dt} = \frac{\partial \log F}{\partial t} = a \cdot s
\]

(5)

which is the semi-log elasticity of flows (F) with respect to travel time (t) and is obtained as the product of the distance decay gradient (a) from the gravity models estimated in section 4 and the (assumed) average speed (s) in the system. It measures the proportionate change in interactions given a unit change in travel times. Assuming that this relationship is constant, an increase in average speed is associated with a reduction in the distance decay gradient \(a\), reflecting the fact that with the higher speed distance becomes less of an obstacle to interaction.

The potential magnitude of the agglomeration benefits associated with improvements in travel time due to a new high-speed rail connection is obtained using the method below.

\[
WEI_{HS} = \left[ \sum_{k=1}^{3} w_k \cdot \frac{\Delta ED}{ED} \right] \epsilon_{ED}^\gamma \cdot GDP
\]

(6)

where:

- \(w_k\) is the proportion of long-distance flows (inter-TTWAs) for purpose \(k\), with \(k\) equal to 1 (HBW), 2 (HBEB), and 3 (NHBEB);
- \(ED\) is a measure of effective density, defined below;
- \(\epsilon_{ED}^\gamma\) is the output elasticity with respect to effective density (taken from Graham et al., 2009);
- \(GDP\) is the Gross Domestic Product.

The Effective density (ED) is defined as illustrated in equation (7) below:

\[
ED = \sum_{i}^{N} ED_i = \sum_{i}^{N} \sum_{j}^{M} \left( \frac{A_j}{\exp(\alpha_{SD}d_{ij})} + \frac{A_j}{\exp(\alpha_{LD}d_{ij})} \right), \quad i \neq j
\]

(7)

where \(A_j\) is the measure of the level of opportunities at destination PASS3 zone \(j\), \(SD\) stands for short-distance and \(LD\) for long-distance. \(A_j\) is represented by PASS3 zone population for
HBW flows, PASS3 zone population and employment for HEBB flows, and PASS3 zone employment for NHBEB.

The change in the effective density resulting from an increase in the average speed of long-distance flows following some transport investment is incorporated through a new (smaller) distance decay gradient $\alpha^{LD}$:

$$\frac{\Delta ED}{ED} = \frac{ED^1 - ED^0}{ED^0} = \sum_{i} \sum_{j} \left\{ \frac{A_j}{\exp(\alpha^{SD} \cdot d_{ij})} + \frac{A_j}{\exp(\alpha^{SD} \cdot d_{ij})} \right\} - \sum_{i} \sum_{j} \left\{ \frac{A_j}{\exp(\alpha^{LD} \cdot d_{ij})} + \frac{A_j}{\exp(\alpha^{LD} \cdot d_{ij})} \right\}$$

Where the after HS distance decay gradient, $\alpha^{LD}$, is:

$$\alpha^{LD}_1 = \left( \frac{\partial \log}{\partial d} \frac{\partial d}{\partial t} \left|_{s^{LD}} \right. \right)^{-1}$$

and the after HS average speed, $s^{LD}_1$, is:

$$s^{LD}_1 = ks_0^{LD}, \quad k > 0$$

Thus, in our approach, the distance decay parameter is assumed non-constant and is revised following some transport intervention. The intuition here is that improvements in travel times will reduce the extent to which travellers perceive distance as an obstacle to interaction.

5.3. Agglomeration order of magnitude scenarios

To give an idea of the orders of magnitude of agglomeration benefits that could arise from investments affecting long-distance movements we provide below some illustrative
calculations. We would like to stress that these are illustrative only, and should not be taken as estimates of the likely agglomeration effects of high-speed rail.

Table 6 below summarises the values obtained for each of the terms included in equation (6) above, and gives an order of magnitude for agglomeration benefits according to two scenarios.

Scenario 1 – we assume a 25% improvement in travel times for all inter-TTWAs trips. We then use a rail modal share of 6.7% (transport statistics GB) and assume that 8.56% are long-distance (inter-TTWAs) trips. We make the calculations for a transport investment that will be able to directly affect 25% (hypothesis A) and 50% (hypothesis B) of all national long-distance rail trips.

Scenario 2 – is the same as scenario 1 only this time assuming a 50% improvement in travel times for all inter-TTWAs trips.

Under scenario one, the distance decay gradient falls from 3.9% to 3.2% for HBW flows, from 0.4% to 0.32% for HBEB flows, and from 0.35% to 0.28% for NHBEB flows. Assuming mode share and affected trips as described above, we estimate an agglomeration benefit of 0.0006% (0.0011%), which corresponds to about £8.29 (£16.57) million for hypothesis A (hypothesis B).

Under scenario two, the reduction in the distance decay gradients is greater because the increase in average speeds is twice as greater (50%). The distance decay gradient falls from 3.9% to 2.6% for HBW flows, from 0.4% to 0.27% for HBEB flows, and from 0.35% to 0.23% for NHBEB flows. Keeping the same assumptions on rail and HS2 shares, we estimate an agglomeration benefit of 0.0011% (0.0022%), which corresponds to about £15.80 (£31.60) million for hypothesis A (hypothesis B).
### Table 6: Agglomeration benefits from HS2

<table>
<thead>
<tr>
<th></th>
<th>HBW</th>
<th>HBEB</th>
<th>NHBEB</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\alpha^{LD}) before HS2</td>
<td>-0.0394</td>
<td>-0.0040</td>
<td>-0.0035</td>
</tr>
<tr>
<td>Relative change in Flows for unit change in travel time</td>
<td>-3.70</td>
<td>-0.99</td>
<td>-0.88</td>
</tr>
<tr>
<td>Average travel time(^1) before</td>
<td>27 min.</td>
<td>39 min.</td>
<td></td>
</tr>
<tr>
<td>Share of each purpose (K) in LD flows ((w_K))</td>
<td>0.61</td>
<td>0.17</td>
<td>0.22</td>
</tr>
<tr>
<td>Share of rail(^2)</td>
<td>6.70%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Share of LD operators in rail trips(^3)</td>
<td>8.56%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Share HS2 in LD rail trips</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hypothesis A</td>
<td>25%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hypothesis B</td>
<td>50%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output elasticity with respect to effective density(^4)</td>
<td>0.04</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GDP (Emillion)(^5)</td>
<td>1,446,113</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Scenario one: +25% speed**

| \(\alpha^{LD}\) after HS2 | -0.0315 | -0.0032 | -0.0028 |
| Change in ED (\(\Delta ED/ED\)) | 0.11  | 0.10   | 0.09    |

**Hypothesis A - Share HS2 in LD rail trips is 25%**

WEI from HS2 (%) | 0.0006% |
WEI from HS2 (Emillion) | 8.29 |

**Hypothesis B - Share HS2 in LD rail trips is 50%**

WEI from HS2 (%) | 0.0011% |
WEI from HS2 (Emillion) | 16.57 |

**Scenario two: +50% speed**

| \(\alpha^{LD}\) after HS2 | -0.026  | -0.0027 | -0.0023 |
| Change in ED (\(\Delta ED/ED\)) | 0.21  | 0.17   | 0.15    |

**Hypothesis A - Share HS2 in LD rail trips is 25%**

WEI from HS2 (%) | 0.0011% |
WEI from HS2 (Emillion) | 15.80 |

**Hypothesis B - Share HS2 in LD rail trips is 50%**

WEI from HS2 (%) | 0.0022% |
WEI from HS2 (Emillion) | 31.60 |

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2. Transport Statistics GB. Excluding walk and bicycle trips. Rail includes "surface rail/underground".
3. HS2.
4. Graham et al., 2009.
5. ONS for 2008 (Blue Book 2009 UK National Accounts).

### 5.4. Summary

- Using estimates from gravity models we can infer possible changes in travel behaviour resulting from investments in long-distance travel.
• We adopt an approach that assumes constancy of trip decay with respect to equal average travel times but variability with respect to distance.

• The intuition is that improvement in travel times will reduce the extent to which travellers perceive distance as an obstacle to interaction.

• Assuming a long-distance mode share for rail of about 7% and that nearly 9% of rail trips are long-distance (inter-TTWAs) trips we make calculations for a transport investment that could directly affect 25% (50%) of long-distance rail trips. The orders of magnitude of agglomeration benefits corresponding to a 25% increase in speeds are about £8.29 (£16.57) million. The orders of magnitude of agglomeration benefits corresponding to a 50% increase in speeds are about £15.80 (£31.60) million.

• The results show very small potential agglomeration benefits.
6. Conclusions

This report has considered the scope for agglomeration based wider economic impacts (WEIs) in the context of high-speed rail investment. It has provided an overview of the theoretical mechanisms that drive agglomeration based WEIs, generated new empirical evidence on long-distance travel, and provided an indicative assessment of the potential order of magnitude of agglomeration benefits from long distance transport improvements.

Theory suggests that the main sources of agglomeration externalities are due to labour market pooling, knowledge spillovers, and efficiency in input-output linkages. Empirical work provides evidence consistent with the existence of agglomeration economies, with estimates of productivity effects lying in the range 1% to 10%. Existing evidence also generally indicates that the geographic scope of agglomeration externalities is relatively localized, but there is little evidence for the actual rate of decay of agglomeration effects.

There are good reasons to believe that transport investments can impact on the microfoundations of agglomeration. Furthermore, there are no obvious characteristics of the sources or mechanisms of agglomeration discussed in the literature that would limit their generation over longer distances. Thus, most of the arguments linking transport to agglomeration could hold in long-distance case in the sense that if spatial interactions between economic agents are made more efficient we may expect increasing returns.

Evidence on the spatial distribution of commuting and business flows shows that there is a considerable amount of long-distance interactions between TTWAs. This suggests that high-speed rail could have an important effect on the level of connectivity between firms and workers.

Using estimates of the distance decay gradient from gravity models it is possible to infer changes in flows resulting from improvements in travel times. To obtain the distance decay gradient of long-distance commuting and business movements, gravity models are estimated using data on commuting flows and business flows from the NTM. The estimates for the distance decay gradients suggest that commuting flows are more responsive to distance than business flows. An increase of one kilometre in commute lengths produces a reduction in long-distance HBW flows of about 3.9%. An increase of one kilometre in business distances produces a reduction in long-distance HBEB and long-distance NHBEB flows of about 0.4% and 0.35% respectively.
To estimate potential agglomeration benefits from improvements to long distance travel we adopt an approach that assumes constancy of trip decay with respect to equal average travel times but variability with respect to distance. The intuition is that improvement in travel times will reduce the extent to which travellers perceive distance as an obstacle to interaction. Assuming a long-distance mode share for rail of about 7%, and that 8.56% are inter-TTWA trips, we make calculations for a transport investment that can directly affect 25% (50%) of all national long-distance rail trips. The order of magnitude of agglomeration benefits corresponding to a 25% increase in travel speeds shows very small potential agglomeration benefits of 0.0006% or £8.29 million (0.0011% or £16.57 million). For an increase of 50% in travel speeds the potential agglomeration benefits are of 0.0011% or £15.80 million (0.0022% or £31.60 million).

Thus, while urban economic theory does not preclude the existence of agglomeration benefits across inter-regional distances, the empirical evidence suggests that these may be very small indeed.
References


