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Investigating the link between productivity and agglomeration for UK industries.

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Summary

Agglomeration economies are positive externalities that arise through the spatial concentration of economic activity. According to urban economic theory, firms derive productive advantages from locating in close proximity and the existence of such benefits can explain the formation and growth of cities and dense industrial areas. The main sources of agglomeration externalities are thought to arise from improved opportunities for labour market pooling, knowledge interactions, specialisation, the sharing of inputs and outputs, and from the existence of public goods. As the scale and density of urban and industrial agglomerations increase, we expect to find an increase in the external benefits available to firms.

There is an inherent relationship between transport and the externalities of agglomeration. The prevalence of transportation costs is crucial in generating tendencies towards spatial concentration, and in fact, the level of urban or industrial density experienced by any firm is partly dependent on the nature of transport provision. This is because transport systems to some extent determine *proximity*, or the ease of access, to other firms and to labour markets. In effect, transport can change urban or industrial densities by rendering a larger scale of activity more accessible.

From this line of reasoning it is clear that there may be consequences of transport investment that relate specifically to agglomeration. Essentially, the argument is that if there are increasing returns to spatial concentration, and if transport in part determines the level of concentration or density experienced by firms, then investment in transport may induce some shift in the productivity of firms via the externalities of agglomeration. These particular effects of transport investment are referred to as *wider economic benefits* because they represent market imperfections that are not accounted for in a standard cost-benefit appraisal.

To understand the magnitude of the potential wider benefits of transport investment we first need quantitative estimates of the returns to agglomeration. In other words we re-

quire some empirical verification of the existence and magnitude of the relationship between productivity and urban density. Preferably, we want to examine this relationship separately for different sectors of the economy because we know that some sectors are more urbanised than others and thus likely to gain more from increasing densities.

This report presents findings of research commissioned by the Department for Transport (DfT) into the relationship between agglomeration and productivity. It presents results for different industrial sectors that estimate how productivity varies with the level of agglomeration in the UK.

The results show that agglomeration economies do exist and that they can be substantial, particularly for services. If transport investment changes the densities available to firms, for instance through a reduction in travel times or in the cost of travel, then there are likely to be positive gains from agglomeration.

The main findings of the report are as follows.

- There is no evidence of agglomeration externalities for primary sector firms. Positive agglomeration economies tend to be present in most service industries while the evidence for manufacturing industries is mixed.
- We calculate a weighted average agglomeration elasticity of 0.07 for manufacturing and 0.129 for the service sector. The elasticity of productivity with respect to agglomeration for the economy as a whole is 0.125, implying that a 10% increase in the level of agglomeration is associated on average with a 1.25% increases in aggregate productivity.
- Diminishing returns to agglomeration are evident in some industries, causing the magnitude of agglomeration elasticity to dip as effective densities increase. The exceptions are real estate, retailing, financial services, and business & manage-

ment consultancy for which the elasticities tend to be highest in the most urbanised locations.

- Use of a generalised cost (i.e. travel time and money cost) based measure of effective density produces higher agglomeration elasticities because it captures both time and distance dimensions of effective density.
- Comparing estimates of agglomeration economies based on generalised cost to those based on distance suggests that diminishing return to agglomeration can be partly explained by congestion in highly urbanised locations.

1 Introduction

This report is concerned with the nature and magnitude of the relationship between agglomeration and productivity. It describes the results of new empirical research on this theme for different sectors of the UK economy. The substance of the report is taken from Graham (2005, 2006), and the intention here is to provide only an overview of the major empirical finding of this previous work. For a full description of methodology, data sources, or other technical aspects of the research the reader should refer to these more detailed reports.

The context for this research relates to the issue of whether there are external benefits that arise from the provision of transport investment that are not included in a standard transport appraisal, so called *wider economic benefits*. Venables (2005) has argued that by impacting upon urban densities transport improvements could have external benefits due to the existence of a systematic relationship between agglomeration economies and economic productivity.

This report does not address directly the issue of transport appraisal and the existence of wider economic benefits. Rather, it provides evidence that allows us to evaluate whether there may actually be a systematic relationship between agglomeration and productivity. To understand the magnitude of the potential wider benefits of transport investment we first need quantitative estimates of the returns to agglomeration. In other words we require some empirical verification of the existence and magnitude of the relationship between productivity and urban density. Preferably, we want to examine this relationship separately for different sectors of the economy because we know that some sectors are more urbanised than others and thus likely to gain more from increasing densities.

The results presented in this report indicate that agglomeration economies do exist and that they can be substantial, particularly for services. If transport investment changes the densities available to firms, for instance through a reduction in travel times or in the cost of travel, then there are likely to be positive gains from agglomeration.

2 Productivity and agglomeration: a review of the literature.

The tendency towards concentration or agglomeration is perhaps the most widely observed feature of the spatial organisation of economic activity. It can be discerned across the Globe at a variety of different geographical levels. Agglomeration is evident, for instance, in the existence and growth of cities, in the formation of industrial regions and districts, and in the clustering of like activities within the same neighbourhood of a town or city.

Attempts to explain the microfoundations of agglomeration generally start from the premise that cities and industrial concentrations would not form if there were not some tangible benefits that accrued to the firms. The advantages derived through the spatial concentration of economic activities are referred to generically as agglomeration economies. They are principally thought to be sourced through improved opportunities for labour market pooling, knowledge sharing or the transmission of technological spillovers, specialisation, the existence of local public goods, and the sharing of inputs and outputs¹.

An important point concerning the benefits of agglomeration is that they are classed as positive *externalities*. That is, they arise as a side effect of the activities of firms which have consequences for the wider economy. The concept can be outlined as follows. If a firm locates in some existing urban concentration, then assuming rational behaviour we can expect that firm to evaluate the productivity advantages it faces in choosing or remaining in that location, but we would not expect it to consider the impact that its presence has on other activities located nearby. In other words, by locating close to other activities a firm induces some benefit that it does not itself fully enjoy. The benefit is external.

¹ There are a wide variety of explanations for agglomeration. Fujita and Thisse (2002) and Fujita et al (1999) survey some important developments in urban economic theory used to explain agglomeration and Duranton and Puga (2004) provide a useful demonstration of the microfoundations of agglomeration.

Supplementary to the arguments which point to the existence of positive agglomeration economies, it is also important to acknowledge that there are limits to urban growth and that cities can experience declines in population, employment and even economic output. Urban economic theory generally explains such *diminishing returns* through the existence of *agglomeration diseconomies*, which ultimately give rise to a trade-off in highly urbanised environments between the productive advantages available to firms and the increased costs of trade. Examples of agglomeration diseconomies include congestion, heightened competition and higher prices for land and other factor inputs, and more intense competition in output markets. The degree to which a favourable trade-off between agglomeration economies and the costs of trade can be reached in any particular location is to a large extent specific to the nature of the economic activity being undertaken.

The theory of agglomeration has provided one of the most persistent theme of interest in the spatial economic disciplines (see Fujita and Thisse 2002 for a comprehensive up-to-date discussion of the theory). A body of empirical work, stretching back over many years, has sought to identify these externalities and to quantify their effects on productivity. There are a number of excellent up-to-date surveys of the empirical literature on agglomeration (see in particular Rosenthal and Strange 2004, Eberts and McMillen 1999).

Table 1 provides a summary of some prominent studies of the effects of agglomeration on manufacturing productivity. The level of agglomeration or urbanisation is typically modelled empirically by using some measure of the ‘scale’ of a location, such as total population or total employment. The agglomeration variable is then included in a regression which also contains the standard variables specified in a production or cost function.

Table 1. Estimates of agglomeration economies from previous studies.

Author	unit of analysis	independent variable	elasticity
Aaberg (1973)	Swedish cities	city size (population)	0.02
Shefer (1973)	US MSAs	RTS at MSA aggregation	0.20
Sveikauskas (1975)	US MSAs	city size (population)	0.06
Kawashima (1975)	US MSAs	city size (population)	0.20
Fogarty and Garofalo (1978)	US MSAs	city size (population)	0.10
Moomaw (1981)	US MSAs	city size (population)	0.03
Moomaw (1985)	US MSAs	city size (population)	0.07
Nakamura (1985)	Japanese Cities	city size (population)	0.03 ^a
Tabuchi (1986)	Japanese Cities	city size (population)	0.04
Louri (1988)	Greek Regions	city size (population)	0.05
Sveikauskas et al (1988)	US MSAs	city size (population)	0.01 ^b
Ciccone and Hall (1996)	US States	employment density	0.06
Ciccone (2002)	EU regions	employment density	0.05

Notes: MSA - Metropolitan Statistical Area, a - mean value for 14 industries, b - mean value from 5 model specifications.

The estimates of agglomeration economies for manufacturing industries shown in table 1 range from 0.01 to 0.20, but the majority of values are under 0.10. This indicates that a doubling of city size is typically associated with an increase in productivity of somewhere between 1% and 10%. So the literature does find evidence of increasing returns to urban density for manufacturing industries.

3 Measuring and estimating agglomeration externalities

The previous literature has indicated that agglomeration externalities do exist for manufacturing, but the sectoral coverage of existing work is incomplete and the analysis of agglomeration is typically based on data for relatively aggregated industries and spatial areas.

The purpose of the research described in this report is to estimate a set of agglomeration elasticities for detailed sectors of the economy, including services, which are more compatible with the objective of assessing the wider economic benefits of transport investment. We use a highly flexible measure of density that incorporates an implicit transport dimension. We do this to find out whether these agglomeration externalities really exist and to give an indication of whether they might be important in assessing the benefits of transport investment.

Measuring agglomeration

As discussed in the literature survey, previous research has typically used total metropolitan population or employment to provide an empirical measure of city size. Such simple measures of agglomeration are not appropriate for the task at hand in this report. There are no good sources of data for British metropolitan areas and the aggregate data that do exist are for administrative areas that do not readily correspond to cities.

More importantly, there are several difficulties that arise when we try to set boundaries to define distinct metropolitan areas. For instance, while Greater Manchester and Liverpool are nominally two separate cities, there is interaction between the two over relatively small distances that arguably prevents them from being truly distinct. Likewise it is conceivable that a firm located outside the London conurbation can still enjoy agglomeration benefits through proximity that arise from the scale of London and its industries.

The point is that we do not wish to place arbitrary a priori restrictions on the geographic scope of agglomeration that correspond to some pre-defined boundaries. Crucially, we are not just interested in city size or scale, but also in the relative proximity of activities. This leads naturally to a consideration of densities and in this research the measures of agglomeration we adopt are based on the concept of *effective densities*. These densities are calculated for very small areas of the country. Specifically, we use ward level employment to construct a measures of agglomeration experienced by each firm.

The total *effective density* of employment that is accessible to any firm located in ward i is given by

$$U_i = \frac{E_i}{r_i} + \sum_j^{i \neq j} ([E_j] \cdot d_{ij}) \quad (1)$$

where E_i is total employment in ward i , r_i is an estimate of the radius of the ward², E_j is total employment in ward j , and d_{ij} is the distance between i and j .

It is worth stressing here that our measure of agglomeration is designed to contain an implicit transport dimension: proximity. The measure of proximity used in equation (1) is based on straight-line distance and is calculated using Pythagoras and the x and y coordinates of the ward centroid. In addition, we have used information on the ward to ward generalized costs of travelling by road supplied by the UK Department for Transport. The generalised cost of road travel by car captures not just the distances between wards, but also how long it takes to get from one ward to other. In other words, this measure of proximity takes variance in speeds into account and so is useful in analysing the impact of road traffic congestion on agglomeration.

In this way we generate effective density measures of agglomeration that have a number of desirable properties:

² The radius is approximated from the ward area as $\sqrt{\text{area}_i / \pi}$

- i. They allow for a highly flexible spatial framework which is not constrained by predefined spatial units such as administrative areas or metropolitan definitions.
- ii. The densities incorporate an implicit transport dimension because they reflect the importance of the scale and proximity (accessibility) of economic activity to each firm.
- iii. They can be calculated for very small areas of the country (i.e. the 10,780 wards of Britain) allowing for a high degree of spatial detail in analysis.
- iv. By using a measure of proximity based on distance and generalised cost they can be used to represent the time and cost, as well as physical, dimensions of density.

Estimating the link between agglomeration and productivity

As externalities, agglomeration economies are typically treated as a kind of technology component that serves to shift the firm's production or cost functions. For instance, at the firm level a typical specification of the production function would be

$$Y = g(U)f(X,) \quad (1)$$

where Y is the output level of the firm, X is a vector of factor inputs, and $g(U)$ is a vector of influences on production that arise from agglomeration economies.

We use firm level data to provide an empirical representation of the type of production function outlined in equation (1), allowing us to estimate the effect of agglomeration on firm productivity. This is achieved by specifying a variant of the translog production function which includes a primary production function along with a set of inverse input demand equations³. Using this particular approach we can sketch out a reasonably complete specification of the production technology of firms which allows us to analyse the effects of agglomeration on productivity.

³ For a full description of the use of the translog production inverse input demand function for the analysis of agglomeration see Graham (2006) and Graham and Kim (2006).

The firm level data we use are based on the accounts of registered UK companies. We have extracted the data over the period 1995 to 2002 for 28 industry groups (see appendix 1). We have extensive financial data for each company including turnover, a breakdown of costs, and information on wages, the number of employees, and on the capital assets held by the firms. The data also give information the location of the company.

Selecting only those companies that have plants at a single location we are able to locate each firm on a map using Geographical Information System (GIS) software. We then overlay a ward level map and allocate each firm to one of the 10,780 wards of Britain. At the ward level we have employment data from the Annual Business Inquiry (ABI) that allows us to construct our measures of agglomeration.

In this way we build up a database that describes the production characteristics of UK firms in different industrial sectors, and that also has some measures of the agglomeration experienced by each firm.

4 Results.

In this chapter we present estimates of the relationship between agglomeration and productivity for UK industries derived using the production function methodology outlined in chapter 3. The results are expressed as elasticities of productivity with respect to agglomeration. These can be interpreted as showing the proportional change in productivity associated with a proportional change in the level of agglomeration.

Table 2 below shows estimates of the elasticities of productivity with respect to agglomeration for our 28 industry groups.

Table 2: Estimated elasticities of productivity with respect to agglomeration.

Industry	SIC codes	elasticity
Primary	SIC 01 to 14	-0.042
Food manufacture	SIC 15	0.084**
Manu. of Textiles	SIC 17 & 18	0.121
Manu. of wood & wood products	SIC 20	0.069*
Manu. of paper & paper products	SIC 21	0.121
Publishing & printing	SIC 22	0.105**
Manu. of chemicals	SIC 24	-0.008
Manu. of rubber & plastics	SIC 25	-0.155**
Manu. of metals & metal products	SIC 27 & 28	0.030
Manu. of office machinery & equip	SIC 30	0.168
Manu. of radio, TV & communications	SIC 32	0.382**
Manu. of medical & precision equip.	SIC 33	-0.191**
Manu. of motor vehicles	SIC 34 & 35	0.121
Electricity, gas and water	SIC 40 & 41	0.090
Construction	SIC 45	0.191**
Wholesale & retail	SIC 50 to 52	0.041**
Hotels & restaurants	SIC 55	0.224**
Transport services	SIC 60 to 63	0.325**
Post & telecommunications	SIC 64	-0.008
Finance & insurance	SIC 65 to 67	0.251**
Real estate	SIC 70	0.084**
IT services	SIC 72	0.034*
Business & management consultancy	SIC 7414	0.298**
Architecture & engineering	SIC 742	0.066**
Advertising	SIC 744	0.137**
Labour recruitment / personnel	SIC 745	0.023
Public admin, education & health	SIC 75 to 90	0.292**
Media services	SIC 921 & 922	0.222**

Note: ** - significant at 0.01, * - significant at 0.05

The industries shown in table 2 above can be divided into four broad classes: primary (SIC 01 to 14), manufacturing (SIC 15 to 40&41), construction (SIC 45), and Services (SIC 50 to 921 & 922).

For the primary industries the elasticity estimate is insignificant and we cannot therefore reject the null hypothesis that there is no agglomeration effect on productivity. This result appeals to intuition in so far as we know that primary activities tend to take place outside of cities and large urban areas.

For the manufacturing industries we estimate positive and significant agglomeration economies for 5 sectors: the manufacture of food (SIC 15) (0.084), the manufacture of wood & wood products (SIC 20) (0.069), publishing printing & recorded media (SIC 22) (0.105), the manufacture of radio TV & communications equipment (SIC 32) (0.382), and construction (SIC 45) (0.191).

The remaining estimates for the manufacturing industries are either statistically insignificant, or in the case of SIC 25 and SIC 33, significant but negative⁴. For these sectors we cannot therefore discern any productive advantage to firms that accrue from increasing effective employment density.

Thus we find mixed evidence about the effect and strength of agglomeration economies for the primary and manufacturing sectors. However, the results do have intuitive appeal. For instance, the fact that we do not find agglomeration externalities for the primary industries seems reasonable because we know that activities related to agriculture, forestry, fishing & mining typically tend to take place away from large town and cities and close to natural resources. For similar reasons, we may not be surprised that we find a weak

⁴ For manufacturing industries negative estimates could be indicative of some systematic spatial variance in functions. For instance, dense urban areas could perhaps host mainly repair or smaller scale ancillary workshops, while the major productive activity tends to take place elsewhere. Alternatively, negative estimates could capture the effect of agglomeration diseconomies, for instance, due to more intense competition for outputs and factor inputs and the higher prices that firms face.

agglomeration effect for the production of electricity water & gas in which locational decisions may again be influenced by the occurrence of natural resources.

In contrast, we find positive agglomeration externalities in sectors that manufacture goods for household consumption, and that may therefore benefit from locations close to the markets offered by towns and cities. For instance, publishing and printing (SIC 22), the manufacture of food (SIC 15), the manufacture of radio TV & communications equipment (SIC 32) and construction (SIC 45).

Taking a weighted average of the agglomeration elasticities for the manufacturing sectors, where the weights are based on the proportion of UK manufacturing jobs in each industry, gives a weighted average elasticity of 0.077. This figure compares to similar estimates obtained recently for manufacturing firms by Ciccone and Hall (1996) for the US states (0.06) and Ciccone (2002) for EU regions (0.045).

Turning now to the service industries we find that estimated elasticities are positive and significant for 11 of the 13 industries and insignificant for two: post & telecommunications (SIC 64) and labour recruitment (SIC 745).

Positive externalities are estimated for Wholesale & retail (SIC 50 to 52) (0.041), hotels and restaurants (SIC 55) (0.224), Transport services (SIC 60 to 63) (0.325)⁵, Finance & insurance (SIC 65 to 67) (0.251), Real estate (SIC 70) (0.084), Computer services (SIC 72) (0.034), Business & management consultancy (SIC 7414) (0.298), Architecture & engineering (SIC 742) (0.066), Advertising (SIC 744) (0.137), Public services (SIC 75 to 90) (0.292), Motion picture video & TV (SIC 921 & 922) (0.222).

The order of magnitude of the agglomeration effects is much stronger for some services than for manufacturing sectors. The particularly high elasticities values for business ser-

⁵ The high elasticity for transport providing firms may be indicative of the increasing returns to density which tend to affect transport operators such that unit costs fall as the density of traffic increases. Passenger densities are likely to grow systematically with city size.

vices & management consultancy and financial services are largely unsurprising. We know that these kinds of activities are disproportionately located in large towns and cities and we would therefore expect such locations to induce higher productivity.

Thus, for most service industries there appear to be positive externalities from increasing effective densities. Taking a weighted average of the agglomeration elasticities for the service industries we consider, where the weights are based on the proportion of service jobs in each industry, gives a weighted average elasticity of 0.197.

Estimating the effect of agglomeration in a single model including firms from all industries, gives an estimated elasticity of productivity with respect to agglomeration for the whole economy of 0.125.

Variable returns to agglomeration

So far we have reported estimates of the elasticity of productivity with respect to agglomeration which are constant across the urban hierarchy. This essentially implies that agglomeration economies will continuously give rise to productivity increases as urban densities grow. As mentioned in chapter 2, however, there are reasons why the magnitude of the elasticity could vary spatially, and in particular, there are good reasons for supposing the existence of diminishing returns if agglomeration diseconomies exist.

Accordingly, it is worth considering whether there might be variable returns to agglomeration. We do this here by testing a quadratic form for the agglomeration variable in the primary production function, which allows the elasticity to vary with the level of agglomeration accommodating the possibility of diminishing returns. We would expect the evidence on diminishing return to vary by sector because some industries may be able to achieve a more favourable trade off between agglomeration economies and diseconomies than others.

To ease the presentation of results we analyse diminishing returns for an 11 sector aggregation of the 2 digit industries shown the appendix. These are manufacturing (MAN) (SIC 15-40), construction (CON) (SIC 45), distribution hotels & catering (DHC) (SIC 50-55), transport storage & communications (TSC) (SIC 60-64), real estate (RE) (SIC 70), information technology (IT) (SIC 72), banking finance & insurance (BFI) (SIC 65-67), business services (BUS) ((SIC 741-745), and public services (PSE) (SIC 75-90).

Table 3 below shows results from the estimation of agglomeration economies using the quadratic form $[\beta_{Ued} \log U + \beta_{UUed} (\log U)^2]$. A negative value for β_{UUed} is indicative of the existence of diminishing returns.

Table 3: Elasticities of productivity with respect to agglomeration.

	β_{Ued}	β_{UUed}	elasticity
Manufacturing	1.105**	-0.086**	0.041
Construction	4.79**	-0.369**	0.214
Distrib, hotels & catering	2.488**	-0.188**	0.133
Trans, storage & comm	1.48*	-0.095	0.274
Real estate	0.084**	-	0.084
IT	3.68**	-0.285**	0.089
Banking, fin & insurance	0.251**	-	0.251
Business services	0.176**	-	0.176
Public services	0.292**	-	0.292

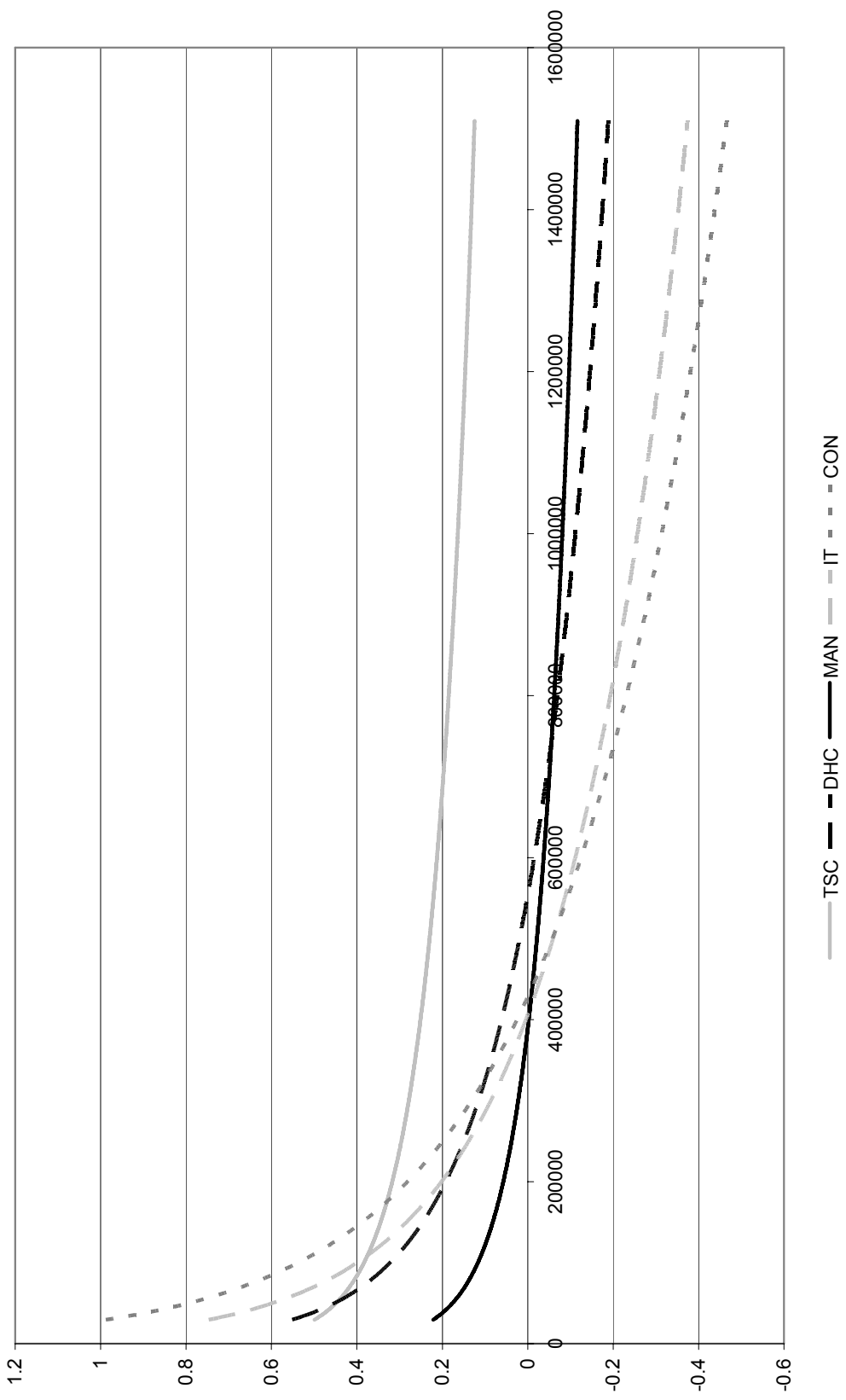
Note: ** - significant at 0.01, * - significant at 0.05

Table 3 shows evidence of diminishing returns to agglomeration for five sectors: manufacturing, construction, distribution hotels & catering, transport storage & communications, and IT. For the remaining four industries we find insignificant quadratic terms but achieve a good fit with a constant elasticity for the sample as a whole indicating that returns to agglomeration are constant.

Figure 1 illustrates the nature of the five quadratic relationships we have estimated by evaluating the agglomeration elasticities for each ward of Britain using the ward agglomeration values. Note that the elasticities vary at each point in the sample and so the plots show the marginal relationship between productivity and agglomeration. Thus, where the elasticities are greater than zero there are increasing returns to agglomeration, where they

equal to zero returns to agglomeration are maximized, and where they are less than zero returns are decreasing.

Figure 1: Spatial variance in returns to agglomeration.



Each of the five sectors shown in figure 1 exhibits some degree of diminishing returns to urban density. For manufacturing, IT and construction, returns to agglomeration are maximized (elasticity = 0) at around the same point. In fact, although this looks to be at a relatively low value of agglomeration the distribution has a right-hand skew and for these three industries we actually find positive but diminishing returns over the first nine deciles of agglomeration values. The distribution hotels & catering industry reaches a maximum value of returns to agglomeration slightly later and then decreasing returns thereafter in a small proportion of the most highly urbanized wards. For transport storage & communications we have evidence of diminishing returns but the quadratic function is not maximized using this sample and we do not identify decreasing returns to agglomeration.

Measuring effective densities: straight line distance and generalised cost.

In chapter 2 of this report it was noted that proximity can be measured by straight line distance or by some measure such as generalised cost, which includes distance and time dimensions in the measure of agglomeration.

In evaluating the impact of agglomeration it is important to recognise that densities can be defined not just physically, but also in terms of the volume of activity that is available within a given time of travel or a given cost of travel. In particular, the presence of congestion in urban transport systems can effectively reduce the density of highly urbanised locations because although there is a lot of activity within a relatively small area, congestion makes this activity difficult to access, giving rise to longer travel times and higher costs of travel.

Here we use a generalised cost based measure of proximity to construct effective densities and compare to these to those based on distance. We also use these results to shed light on the impact of road traffic congestion on the strength of agglomeration externalities.

Figure 2 below compares estimates of agglomeration economies based on straight line distance to those based on generalised cost for each of our 28 industry groups.

The overall pattern of results by industry based on either measure of agglomeration is very similar. However, it is clear from figure 2 that generalised cost based estimates tend, pretty much consistently, to be of higher magnitude than the distance based measures. Positive and significant agglomeration economies are estimated for 15 of the 28 industries shown in the table and in all cases the estimate based on the generalised cost measure of agglomeration is higher than the estimate based on distance.

Calculating weighted average agglomeration elasticity for manufacturing as a whole, where the weights are based on the proportion of manufacturing jobs in each sector, gives a value of 0.08 based on a straight line distance measure of agglomeration and 0.11 using a generalised cost based measure. Similarly, for services the weighted averages are 0.20 and 0.27 respectively.

The reason for this difference in the magnitude of the estimates is the inclusion of information about variance in speeds. Distance based measures of agglomeration do not account for the fact that speeds may vary systematically with city size. In other words, such measures do not recognise congestion diseconomies, and consequently, at the upper bound of the data they produce higher extreme values of agglomeration. In effect, the exclusion of travel time information in the definition of effective density induces a downwards bias on the agglomeration elasticity values for the most urbanised wards.

Of course, another way of interpreting these results is that congestion serves to reduce productivity. If, as our empirical analysis suggests, congestion can give rise to diminishing returns then the implication is that the productivity benefits of agglomeration could be increased by making appropriate transport interventions to reduce the negative externality of congestion.

It is worth noting that from the point of view of transport appraisal use of the generalised cost based estimates may actually be less appropriate than those based on straight line distance. This is because the benefits to business and freight users from congestion reduction are already included in a standard cost benefit analysis and so inclusion of the con-

gestion effect implied by the generalised cost agglomeration estimates could risk some double counting of these benefits.

5 Conclusions

Urban economic theory uses the concept of agglomeration economies to explain the formation and endurance of cities and industrial concentrations. Previous empirical research has identified evidence of agglomeration economies for manufacturing industries.

This report describes research which has sought to identify whether a systematic relationship between agglomeration and economic productivity exists for UK industries. It has presented estimates based on effective density measures of agglomeration for a comprehensive range of industrial sectors. The ultimate objective of the work is to contribute evidence which will allow us to evaluate whether the agglomeration benefits of transport investment are worthy of consideration or not.

The results show that agglomeration economies do exist and that they can be substantial, particularly for services. We calculate a weighted average agglomeration elasticity of 0.129 for the service sector and 0.08 for manufacturing. For the economy as whole we estimate an elasticity of productivity with respect to agglomeration of 0.125.

We also find evidence of diminishing returns to agglomeration for four industry groups: manufacturing, construction, distribution hotels & catering, and transport & communications. For the types of industries that tends to be prominent in large cities and in CBD locations, however, such as real estate, banking & finance, business services, and public services, our estimates show returns to agglomeration that are constant across the distribution of density values.

Use of a generalised cost based measure of effective density produces higher agglomeration elasticities than those derived from a measure using straight line distance. This is because the generalised cost measure captures both time and distance dimensions of density. A comparison of estimates indicates that urban road traffic congestion plays a significant role in ‘constraining’ the benefits of agglomeration, and consequently, it may serve to reduce achievable levels of urban productivity.

Concerning transport provision, the crucial finding from the research presented in this report is that productivity does appear to be associated with economic density. Accordingly, we can hypothesise that an increase in effective densities induced through transport investment may have associated productivity benefits via agglomeration. Agglomeration gives rise to efficiency gains, and transport investment can alter the intensity of this relationship by changing the level of agglomeration available to firms.

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Appendix: Industry groups used for estimation

1. SICs 01 to 14 – Primary industries - agriculture, hunting, forestry, fishing, mining, and extraction
2. SIC 15 - Manufacture of food products and beverages
3. SICs 17 & 18 - Manufacture of textiles, wearing apparel, dying and dressing of fur
4. SIC 20 - Manufacture of wood and wood products
5. SIC 21 - Manufacture of pulp, paper and paper products
6. SIC 22 - Publishing, printing and reproduction of recorded media)
7. SIC 24 - Manufacture of chemical and chemical products
8. SIC 25 - Manufacture of rubber and plastic products
9. SICs 27 & 28 - Manufacture of basic metals and fabricated metal products
10. SIC 30 - Manufacture of office machinery and computers
11. SIC 32 - Manufacture of radio, television and communication equipment
12. SIC 33 - Manufacture of medical, precision & optical instruments, watches & clocks
13. SICs 34 & 35 - Manufacture of motor vehicles and transport equipment
14. SICs 40 & 41 - Electricity, gas and water
15. SIC 45 – construction
16. SICs 50, 51 & 52 – Wholesale and retail trades
17. SIC 55 – Hotels and restaurants
18. SICs 60, 61, 62 & 63 – Land, water, air transport and supporting services
19. SIC 64 – Post and telecommunications
20. SICs 65, 66, 67 - Finance & insurance
21. SIC 70 - Real estate activities
22. SIC 72 - Computer and related activities (IT services)
23. SIC 7414 - Business and management consultancy activities
24. SIC 742 - Architecture and engineering activities
25. SIC 744 - Advertising
26. SIC 745 - Labour recruitment and provision of personnel
27. SICs 75 to 90 – Public administration, education, health, & social work
28. SICs 921 & 922 - Motion picture and video activities, radio and television