Productivity and employment impacts of agglomeration: evidence from transport improvements

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Abstract

This paper estimates the effect of road transport infrastructure improvements on firm productivity and employment. The study uses micro longitudinal datasets on firms and employees in Britain, linked by detailed geographical location to road transport improvements that occurred between 1998 and 2003. We measure to which extent new road infrastructure projects changed employment accessibility (or 'effective density') at locations close to the sites of the projects. We then estimate whether firms in locations that experienced large changes of this type showed productivity improvements relative to those that experienced smaller changes. We do not find evidence that improved accessibility increased total factor productivity within firms, or that firms increased employment at the plant level due after the improvements. However, we find evidence that places (postcode sectors) that experience accessibility improvements close to transport schemes attract more firms and employment, and weaker evidence of productivity improvements at this more aggregated level.

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1. Introduction

It has long been recognised that firms operating in large, dense and well integrated markets are more productive - that is they produce more output, from the same inputs, measured either in real or nominal terms. Theory suggests two reasons for this, one operating at the macro level and one at the micro level. Firstly, at an aggregate macro level, the relationship could arise because of selection effects: in a world of heterogeneous firms, only the most productive firms survive in more integrated and competitive markets (Melitz 2003). Secondly, at the micro level, individual firms may benefit through 'sharing', 'matching' and 'learning' in more agglomerated economies (Duranton and Puga, 2004; Rosenthal and Strange, 2004). '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 of 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.

Over the past 10-15 years, a large number of research studies have estimated the scale of these 'agglomeration' effects, and found them to be positive in many different settings (see Melo et al, 2009; for a review). Usually, the estimates are based on the cross-sectional correlation between employment density and firm productivity (e.g. Graham 2006). Occasionally estimates are derived from the correlation between *changes* in employment density and *changes* in productivity (e.g. Ciccone and Hall, 1996).

It is only a small conceptual step from the observation that firms are more productive in more integrated and dense economies, to the conclusion that improvements in transport networks could improve productivity. Improvements to the road and rail networks bring firms closer to each other and firms closer to workers in terms of travel times and costs. This closer economic integration exposes firms to greater competition, improving productivity at the macro level, and improves the basis for agglomeration economies arising at the micro level.

This paper estimates the effect of road transport infrastructure improvements on firm productivity, employment and wages. The study uses a micro longitudinal datasets on firms and employees in Britain, linked by geographical location to road transport improvements that occurred between 1998 and 2003. We measure to what extent new road infrastructure projects changed employment accessibility (or 'effective density') at locations close to the sites of the projects. We then use statistical analyses to estimate whether firms in locations that experienced large changes of this type showed productivity improvements relative to those that experienced smaller changes.

The central methodological approach is regression estimation of production and employment functions at the firm level and at postcode sector level using micro-data from the ONS Annual

Respondents Database. We measure potential exposure to the benefits from transport improvements by calculating road-network-based employment accessibility indices for firm locations, both before and after the transport improvements take place. A source of bias with analysis of this kind is that transport schemes may be targeted at areas of high or low productivity, or increasing or declining productivity. As noted by Graham et al (2010), in their review of causal estimation of agglomeration effects on productivity, there is no consensus about the importance of the endogeneity bias. In any case, in order to minimise it, we compare firms more or less exposed to the transport improvement, before and after the transport improvement occurred, using a difference-in-difference style methodology. This methodology removes bias induced by fixed productivity differences between locations that are more exposed to transport improvements and those that are less exposed. To improve on the comparability of areas in terms of differential trends in productivity, we progressively narrow the geographical scope of our samples to focus on firm locations that are close to the sites of transport improvement projects. This approach takes advantage of the fact that many of the areas that gain the most in terms of accessibility are very close to the sites of transport schemes, and benefit incidentally from policy targeted to improve the through-flow of traffic to locations further afield.

Improvements in transportation infrastructure affect performance of firms and regions both directly and indirectly (Vickerman, 2007). On the one hand, it improves logistics and internal organisation of the firm. Transportation services enter the production function as inputs and change output and employment through labour/transportation substitution effects (Holl, 2006). On the other hand, improvements in transport infrastructure have what have been called “wider-economic benefits” (Graham, 2007). Increased accessibility affects the equilibrium between the attraction (agglomeration) and the dispersion (increased competition and congestion) forces and therefore changes the spatial distribution of economic activities (Ottaviano, 2008). Depending on the initial level of transportation costs and on the changes induced by the transport improvements, the new equilibrium may imply higher economic concentration (in order to exploit increasing returns to scale and agglomeration economies) or higher economic dispersion (in order to benefit from lower competition and costs in the periphery and improved access to market).

Even if some authors have explicitly included the role of transportation into the spatial economics analysis (Combes and Lafoucarde, 2001; Puga, 2002; Behrens et at, 2004; Venables, 2007), there is still need to link further the transport and spatial economics literatures (Holl, 2006). Most of the empirical evidence of the effects of transport and infrastructure investment on economic outcomes has been provided at the macro-level and it has focused the impacts of investment in road and public infrastructure on several economic outcomes (Martin and Rogers, 1995; Boarnet, 1998; Chandra and Thompson, 2000; Gibbons and Machin, 2005; Michaels, 2008; Jiwattanakulpaisarn et al, 2010). Only a handful of papers have studied the effect of increased accessibility on firms’ outcomes, and they have mostly focused on the analysis of relocation (Coughlin and Segev, 2000; Holl, 2004a and 2004c) or firm birth (Holl, 2004b). Although using a different methodology from ours, Holtz-Eakin and Lovely (1996) find no effect of public infrastructure on aggregate productivity and a positive effect on the number and variety of plants. Our paper aims to contribute to this literature by providing new evidence on the links between increased accessibility and productivity and employment.

Another contribution of our paper is therefore to perform the analysis at the micro-level (firm) and at a very detailed geographical scale. As remarked by some authors (Moreno and Lopez-Bazo, 2007; Ottaviano, 2008), most of the impact of infrastructure investment on economic outcomes occurs at the local level, so more evidence on the intra-regional and local effects using small geographies is needed (Holl, 2007). Although there exist some evidence on the effects of increased agglomeration on productivity for the UK (Rice et al, 2006; Graham, 2007b), our paper is, to our knowledge, the first one to assess these effects at the firm and the plant levels.

The main finding of the paper is that we can, in general, detect no statistically significant productivity effects at the firm level. We find evidence on positive employment effects at the postcode sector level. These effects are likely to be due to firm mobility and start-ups. We also find some indication that productivity measured at the postcode sector level may have increased, but these effects may be due to sorting of more productive firms to areas with higher effective density.

The rest of the paper is structured as follows. Section 2 presents the empirical methodology and explains the construction of the accessibility, productivity and employment measures. Section 3 describes the data used, while in section 4 the empirical results are presented and discussed. Finally, section 5 we conclude.

2. Empirical methodology

Subsections 2.1 to 2.4 describe the empirical strategies used and Subsections 2.5 – 2.6 discuss the measurement of effective density/accessibility.

2.1. Estimation of firm level productivity and employment effects

The basic method adopted in this study is to carry out regression analyses to estimate the average effect of changes in accessibility induced by transport changes, on a firm's employment and Total Factor Productivity (TFP). The data set used in the productivity regression is the Annual Respondents Database (ARD), and is described in Appendix A. Employment regressions are estimated for Local Units (plants) in the IDBR dataset. Productivity regressions are estimated using data at the Reporting Unit level, which corresponds to firms or subdivisions of firms, and at the local area (postcode-sector) level.

The underlying empirical model of these outcomes has a component A that depends on the economic mass/agglomeration/employment accessibility of the location j in which the firm i is sited (j will correspond to the postcode sector in our empirical work):

$$y_{ijt} = \beta A_{jt} + x'_{ijt}\gamma + \mu_{ij} + \tau_t + \varepsilon_{ijt} \quad (1)$$

Here, y is the outcome of interest (employment, value-added, value-added per worker) for a firm *i*, in location *j* at time *t*, *A* is a measure of employment accessibility along the transport network at location *j* (representing agglomeration, and described below), and *x* represents other firm inputs (labour and capital) and area characteristics (distances to various transport facilities, measure of local skill levels in the residential population) on which we have data. The model includes firm fixed effects μ, which represents the unobserved time invariant productivity component of firms. The fixed effects pertain to firms/plants that remain in situ in their current location. If the firm/plant moves, we allow the fixed effect to change. The firm fixed effects μ depend partly on unobserved time invariant productivity advantages for all firms located at *j*. Year fixed effects τ represent general changes that influence all firms and locations in the study area in a given year (e.g. macro shocks).

Traditional estimates of agglomeration effects are usually based on OLS estimates of models like (1). These estimates are biased when unobserved firm effects μ are correlated with accessibility - if for example, and as seems likely, better transport connections and higher employment density have evolved in places with productive advantages.

A first step to eliminating these biases is to difference the data over time to eliminate fixed-over-time firm effects μ:

$$\Delta y_{ijt} = \beta \Delta A_{jt} + \Delta x'_{ijt}\gamma + \delta_t + \Delta\varepsilon_{ijt} \quad (2)$$

We use both first differencing and the within transformation in the empirical analysis. This formulation is a starting point for evaluating the effects of transport policy on firms, because transport improvements generate changes in *A* over time which can be exploited in the estimation of β. Note, that this estimation strategy ignores whether or not the specific firms or their employees or customers in fact make any use of the transport improvements that have been put in place. The productivity effects that are estimated are thus analogous to "intention to treat" estimates in the programme evaluation literature, and are the expected productivity changes for firms or areas exposed to the treatment (transport improvement).

In general, the change in accessibility ΔA_{jt} could come through changes in the spatial distribution of employment, or because of changes in the transport network. However, we can ensure ΔA_{jt} only picks up changes in the transport network by calculating accessibility based on the pre-improvement spatial distribution of employment - see discussion of the construction of A (section 2.5) for more detail.

Estimation of (2) using within-firm changes in a panel of firms is only feasible using firms that exist, and appear in the data, both before and after the opening of the transport schemes that are being evaluated. This introduces sample selection issues. Firstly, firms that stay in the location of the transport scheme are likely to be those that can benefit most from it. In addition, there will be sampling-related reasons why some firms appear in our data in multiple years whilst others do not. These caveats aside, estimation of β from the changes within firms over time provides the best guide to the micro-level agglomeration impacts of transport improvements for firms that experience the change in transport costs within an otherwise unchanged operating environment.

2.2. Estimation of 'aggregate' area-level productivity effects

We can also estimate the aggregate changes in productivity and employment that occur at the postcode sector level[1] (or other geographical level). As explained in the introduction, the advantage of using postcode sectors as the geographical units is that they are very small spatial units, so we can identify phenomena that would be unobservable at a higher geography level (Holl, 2006).

Implementing this approach relaxes the requirement that the same firms are observed before and after the transport improvement. The postcode-sector-level components can be estimated from the cross-section of firms in each year. Changes in these area level components can then be regressed on changes in accessibility at the area level.

Formally we use a two step approach. We first estimate a regression of the form:

$$y_{ijt} = x_{it}'\gamma + \eta_{jt} + \varepsilon_{ijt} \qquad (3)$$

using plant level data, where η_{jt} are area-by-year effects to be estimated, and x_{it} includes firm level characteristics. We recover estimates of the area-by-year effects $\hat{\eta}_{jt}$ and regress these on the accessibility variable A_{jt} after differencing to eliminate fixed-over-time area effects as in (2) i.e. we estimate

[1] The postal codes (postcodes) used in the United Kingdom provide very detailed geographical information. They are alphanumeric and usually correspond to a limited number of addresses or a single large delivery point. Postcode sectors codification eliminates the last two digits of the full postcode and so they gather between 15-20 postcodes in average. More information available at: http://www.ons.gov.uk/about-statistics/geography/products/geog-products-postcode/nspd/index.html.

$$\Delta\hat{\eta}_{jt} = \beta\Delta A_{jt} + \Delta u_{jt} \tag{4}$$

using a panel of postcode sectors. We also include control variables in the estimation.

This two-step method provides estimates of the *aggregate* effects of the transport improvements at the geographical level, taking into account firm exit, entry and geographical relocation. In the estimates below we use postcode sectors, but the principle could be applied at broader geographical scales.

2.3. Targeting of transport policy

Both the firm-level estimates from (1) and the area-level estimates from (3)-(4) will produce biased estimates of the productivity effects of transport improvements, if areas with increasing or declining productivity are those that experience the greatest accessibility changes. This implies that $\Delta\varepsilon_{ijt}$ in Equation (1) and Δu_{jt} in Equation (4) are correlated with ΔA_{jt}. The usual reason to suspect this kind of problem is the possibility that transport policy is endogenous to the productivity trends in the targeted locations, i.e. the decision to improve the transport network might be partly driven by productivity trends.

There is a limited amount we can feasibly do to eliminate this potential source of bias. Our main strategy is to focus the empirical analysis on places and firms that are close to the transport improvement sites. In the results section below we present estimates for samples within distances of 10km, 30km and 50km of the sites of improvement. In this way we are comparing closely neighbouring places that differ incrementally in terms of the change in accessibility they experience as a result of the road network improvements. These changes in accessibility close to transport schemes are an incidental by-product of the scheme rather than its intended outcome. The main changes in mean travel times and employment accessibility occur close to the end points of new road schemes, whereas they are typically intended to improve the flow of traffic between cities or areas further away from the improvement. There are also often long delays between commissioning and opening of road schemes, which will weaken any link between pre-existing local productivity trends and the decisions over where to site these projects.

We also control for some salient area-level variables in the regression, namely the share of residents with high qualifications (NVQ level 4 plus, based on Local Authority data from the Labour Force Survey), distances to nearest transport facilities - motorway junctions, rail stations, airports, ports (see Appendix C), and the straight-line distance to the transport scheme itself.

2.4. Pre-post analysis

The methods described above are generally appropriate for evaluation of transport improvements occurring in multiple years in multiple locations. In this case we calculate the accessibility index for each postcode in each year taking account of new road transport infrastructure in the year before. Plants are assigned to postcode sectors according to their location in a given year. We then apply the standard 'within-groups' or the `first differences` estimator to the panel of Reporting Units or the panel of Postcode Sectors.

In order to allow for lagged responses and anticipatory effects, we do the analysis by calculating the accessibility variable for only two points in time: a pre-improvement period 1998 and a post-improvement period 2004. Transport improvements open over the period between the pre and post years and we estimate the average effect of accessibility changes due to changes in different years.

2.5. Defining the accessibility index/effective density/agglomeration index

The accessibility index used is identical in structure to market potential measures used in economic geography (e.g. Harris 1954), and the accessibility indices used more generally in the transport literature (e.g. Ahmed et al 2006, Vickerman et al 1999). This index is a measure of the economic mass accessible to a firm in a particular location, given the local transport network.

Consider a measure of economic activity or other variable of interest, such as employment l. For a firm in an origin location *j* at time *t*, an employment accessibility index A_{jt} is a weighted sum of employment in all destinations k that can be reached from origin *j* by incurring a transport cost c_{jkt} along some specified route between *j* and *k* (e.g. straight line distance, minimum cost route along a transport network). That is, the index has the structure

$$A_{jt} = \sum_{k \neq j} a\left(c_{jkt}\right) l_k \qquad (5)$$

Note, that employment in destination k is fixed at some time-invariant level l_k. In the empirical work below, we fix employment at the level at the first in year in our data sample (1997), This ensures that changes in the accessibility index over time occur only as a result of changes in the costs c_{jkt} (e.g. travel time) and not changes in employment that are unrelated to transport changes. Note, as a consequence, changes in accessibility calculated in this way may understate the true change in employment accessibility arising from transport improvements, if these changes induce shifts in employment towards more accessible areas. As it turns out, we find some evidence that employment movements of this type occurred in response to road transport improvements.

In Equation (7) the value of the weight *a*(.) attached to any destination k is a decreasing function of the cost of reaching destination *k* from origin *j*. Potential weighting schemes include: 'cumulative opportunities' weights $a\left(c_{ijt}\right)=1$ if j is within a specified distance of i, zero otherwise; exponential weights $a\left(c_{ijt}\right)=\exp\left(-\alpha c_{ijt}\right)$; logistic weights $a\left(c_{ijt}\right)=\left[1+\exp\left(-\alpha c_{ijt}\right)\right]^{-1}$ or inverse cost weights $a\left(c_{ijt}\right)=c_{ijt}^{-\alpha}$. See Graham, Gibbons, Martin (2009) for further discussion of these indices. In line with common practice, we use the simple inverse cost weighting scheme $a\left(c_{ijt}\right)=c_{ijt}^{-1}$ in which the cost is the estimated travel time. The precise functional form of the distance decay function in these employment accessibility indices is likely to be of second-order importance.

2.6. Effects on accessibility arising from transport improvements

This type of accessibility/market potential/effective density index can be applied to the study of productivity improvements arising from transport projects, assuming the costs c_{jkt} are calculated using routing along the transport network. This works, because transport improvements change the structure of costs c_{jkt} along the transport network and the structure of costs along routes from *j* to potential destinations *k*. This in turn changes the accessibility index (implying more agglomeration).

For example, consider a transport improvement 'treatment' that involves a journey time reduction on a road link between two nodes *p* and *q*. This treatment will have a first order effect on the costs of the least-cost route between *j* and *k* if:

a) the least-cost route between *j* and *k* passes along the link *p-q* in both the pre and post-improvement periods, such that the transport improvement reduces the cost of the journey along *p-q* and brings employment at destination *k* 'closer' to origin *j* in cost terms.

b) the least-cost route between *j* and *k* bypasses link *p-q* in the pre-improvement period, but switches to use the link *p-q* in the post-improvement period because of the reduction in costs; again this brings employment at destination k 'closer' to origin j in cost terms

There are also 'second order' effects arising when:

c) the least cost route between *j* and *k* bypasses link *p-q* in both the pre-improvement and post-improvement periods. However, journeys between other origin and destination pairs have switched to using the link *p-q*, which reduces congestion on the alternative links in the network used by the routing between *j* and *k*; again this brings employment at destination *k* 'closer' to origin *j* in cost terms.

In the empirical work below we focus only on the first order effects of type a) and b) arising from new transport infrastructure. We have to ignore second order effects of type c) because our road transport network data does not allow us to observe changes in travel time induced by changes in congestion occurring as a result of transport improvements (we have no information on traffic flows observed prior to the improvements).

Changes in cost of all these types imply changes in the accessibility index A_{jt} (i.e. a change in agglomeration). The amount of change in the accessibility index at a location *j* depends on the likelihood that a route between *j* and *k* uses the improved link *p-q*. The idea in our method is to use the changes in the accessibility index at each location *j* to estimate the extent to which firms in location j are "potentially" affected by the transport improvements under investigation. In turn, this change in potential accessibility enters into our productivity regressions, as described in Section 2.1. above.

3. Data setup and sample selection

3.1. IDBR/BSD data

The first component in the construction of the employment accessibility index *A* is a source of geographically localised employment data. We use data from the Interdepartmental Business Register/ Business Structure Database (IDBR/BSD) held by ONS. This dataset holds information on the population of businesses in the UK, with information on employment and industrial classification. In this dataset the plants are referred to as the 'Local Units', which belong to different 'Reporting Units' (firms). The IDBR/BSD records plant location down to the full postcode level, although for our analysis we aggregate employment to postcode sectors (roughly 11,000 postcode sectors). We combine this dataset (linked by reporting unit) with the Annual Respondents database (ARD) which includes more detailed information (as explained below in Section 3.3).

When we construct accessibility index *A* in equation (7) we use employment in a base year: 1997. Fixing the spatial distribution of employment to this base period ensures that changes in *A* are attributable (by construction) only to changes in the transport costs caused by the selected transport schemes, and not to employment relocation (which may be endogenous to increased accessibility).

3.2. NTM road network data and O-D matrix construction

The second component in the employment accessibility index is an origin-destination (O-D) matrix containing the costs c_{jkt} (journey time) between each origin and destination. This matrix is required for both the pre-improvement and post-improvement periods.

We use data on traffic speeds and flows on a generalised primary road GIS network for Great Britain provided by the Department for Transportation (DfT). Traffic flows are modelled from traffic flow census data using the FORGE component of the National Transport Model. We construct the road network for year 1997 – 2003 (end of the year) by using the 2003 network provided by the DfT and information on the opening years of road links.

Using this generalised traffic network, we use the network analysis algorithms in ESRI ArcGIS to compute least-cost (minimum journey time) routes between each origin postcode j and destination postcode k in years 1997 - 2003.

When computing the O-D matrix we apply a limit of 80 minutes drive time in computing the matrix. The estimation sample for production and employment effects is subsequently limited to a maximum radius of 50km of the schemes.

We use journey times in the non-busy direction averaged over all time periods between Monday-Friday 08:00 and 18:00. We focus on non-busy travel directions because the busy travel directions are, in principle, more sensitive to changes in congestion induced by new travel links.

Therefore, the accessibility index *A* is calculated using the postcode-sector employment data from IDBR/BSD, and the postcode-sector-to-postcode-sector O-D travel times in the pre and post periods using equation (7).

It should be noted that the network is highly generalised. Journeys via the minor road network are not modelled. Forbidden turns and one way systems are not modelled. All link intersections are treated as junctions. The changes in accessibility must therefore be regarded as approximate.

3.3. Estimation samples from the IDBR and the Annual Respondents Database (ARD)

For the employment regressions in Section 4.2 we work with a panel of Local Units (plants) from the IDBR (see Section 3.1). For the productivity regressions we use the Annual Respondents database (ARD) which includes information needed to measure value added and capital at the firm level.

In the first part of the production function analysis in Section 4.3 we consider only Reporting Units that appear in at least two years. The unit of analysis are Reporting Units (firms) that have the same Local Unit (plants) location structure in the different years. We treat firms with plants that move location as new observations, since measured changes in accessibility would be due to relocation, not the transport schemes. All the firm level productivity regressions include fixed effects for these stable firms.

Implementation of the methods set out in Section 2.1 for productivity analysis are made more complicated by the fact that the Annual Respondents Database does not provide productivity or other economic data (apart from employment) at the plant level. Instead, economic data on value added and capital is observed at Reporting Unit level, which corresponds to one or more Local Units (plants). We assign to a Reporting Unit (firm) the average of the accessibility index of its component Local Units (plants). We do this using weights that correspond to a Local Unit's share in its Reporting Unit's total employment. We use employment at the first year a Local Unit is recorded in the data, to avoid problems induced by firms endogenously shifting employment between Local Units in response to productivity changes,

In the second part of the production function analysis explained in Section 2.1 and presented in Section 2.2, we construct a panel of postcode sectors and estimate postcode-sector level productivity changes. In this analysis we use all ARD Reporting Units and Local Units, regardless of how many times they appear in the ARD sample over the period.

The Reporting Unit/Local Unit data structure has to be accommodated in this area-level analysis too. The fact that accessibility is relevant at plant level implies that Equation (3) should be estimated at Local Unit level. But the fact that economic data is available only at firm Reporting Unit level implies that Equation (3) should be estimated at Reporting Unit level. There are no perfect ways of resolving this conflict.

The first method we use is to apportion all the economic variables (value-added, capital) to Local Unit level based on Local Unit employment (on which we have data) and estimate Equation (3) at Local Unit level. Allocating outputs and capital in proportion to employment assumes constant returns to scale.

The second method we use is to estimate (3) at Local Unit level, with Reporting Unit economic variables assigned equally to each Local Unit. However, the regression is weighted using the Local Unit's share in the employment of the Reporting Unit to which it belongs. This means we put more weight on plants that take a greater share in Reporting Unit output, and do not discard the information in multi-plant firms. The implicit assumption in this method is that Local Unit production is related to Reporting Unit production by a multiplicative structure[2]. This implies that ln-value-added, and ln-capital are allocated to Local Units in proportion to the Local Unit's employment share.

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[2] That is, assuming the local unit production function has the Cobb-Douglas form, the production structure is:

$$\ln y_{lu} = \pi_{lu} \ln y_{ru} = \pi_{lu}\beta_0 + \beta_1\pi_{lu} \ln k_{ru} + \beta_2\pi_{lu} \ln l_{ru}$$

$$\sum_{lu \in ru} \pi_{lu} = 1$$

$$\ln y_{ru} = \sum_{lu \in ru} \ln y_{lu} = \beta_0 + \beta_1 \ln k_{ru} + \beta_2 \ln l_{ru}$$

We use both of the two methods (apportioning data according to Local Units according to employment shares, and weighting the regressions by Local Unit employment shares) described above.

Both the above methods have the drawback that estimation does not take into account productivity differences between Local Units within Reporting Units. Hence imputed value-added will be too low in plants in high productivity areas, and too high in low-productivity areas. This could clearly be important, when it comes to investigating the effects of local area productivity changes induced by transport improvements.

4. Descriptive statistics and results

4.1. Accessibility indices:

We compute employment accessibility for each postcode sector for each year. In each year, we take account of the new road transport infrastructure that was opened in the previous year when we compute the accessibility indices from the road transport network. Each firm in our data is thus assigned an accessibility index based on the postcode sector in which its local units (plants) are located in a given year. The empirical analysis is thus based on the changing geographical pattern of accessibility as the road transport system evolved over the period 1997-2003.

Table 1 summarises the changes in accessibility (inverse travel-time-weighted employment sum) arising from the transport schemes in 1998-2003. We report the statistics for the 3 distance bands (10km, 30km, 50km) that we will use in the main analysis. Accessibility is measured at postcode-sector level (about 11,000 postcode-sectors). The upper panel reports annual changes in accessibility, middle panel shows long differences between 1998 and 2004 and the lower panel shows long differences excluding zero accessibility changes. New roads and related changes in accessibility between 1998 and 2004 are mapped in Figure 1.

The results in the upper Table 1 show that the annual changes in employment accessibility induced by these road improvements were on average very small. Mean change in employment accessibility is 0.3% within 10 kilometers of new road schemes. The top 1 percent (99th percentile) experienced higher than 6.4% accessibility changes. As we expand the sample away from the sites of the schemes, the mean and highest ranked changes in accessibility all tend to fall. Within 50km of the schemes mean accessibility change was 0.15% and 99th percentile was 3.2%. The middle panel show that when we sum up all the accessibility changes over the period, mean accessibility change increases to 1.8% within 10km of the schemes and 0.9 percent within 50km.

Figure 1 illustrates the spatial distribution of accessibility changes between 1998 – 2004. It is seen that areas close to the new schemes saw greater accessibility increases.

Table 1: *Changes in postcode-sector employment accessibility resulting from transport improvements - all industry sectors*

Year to year changes 1998-2004					
	Mean	Std. Dev.	1st pctile	99th pctile	Obs
10k	0.0031	0.0160	0	0.0644	21054
30k	0.0018	0.0111	0	0.0371	48102
50k	0.0015	0.0102	0	0.0318	58350
Changes from 1998 to 2004 (pre-post setup)					
	Mean	Std. Dev.	1st pctile	99th pctile	Obs
10k	0.0185	0.0373	0	0.1794	3509
30k	0.0110	0.0267	0	0.1128	8017
50k	0.0092	0.0246	0	0.1029	9725
Changes from 1998 to 2004 (pre-post setup), excluding zeros					
	Mean	Std. Dev.	1st pctile	99th pctile	Obs
10k	0.0189	0.0377	0	0.1833	3426
30k	0.0116	0.0274	0	0.1182	7554
50k	0.0106	0.0261	0	0.1109	8492

4.2. Employment and number of plants

The first regression results, presented in Table 2 are Local Unit (plant) level regressions of (log) employment on accessibility using the IDBR data. In order to focus on accessibility changes due to road improvements and not due to mobility, we include fixed effects for local units that stay put in the same postcode-sector. Local units that move are treated as new observations. Only local units within 30km of new road schemes opened in 1998-2003 are included. Results are robust to changing the distance band to 10km or 50km. We present the results separately for six industry sectors. All models include year fixed effects and controls for distance to the nearest transport improvement, distance to other transport facilities (rail stations, motorway junctions, ports and airports) and an aggregated measure of skills in the residential population.

The upper panel of Table 2 shows results for first differenced regressions. The dependent variable is change in the log of local unit employment between year t and t-1 and table shows the coefficients for the change in the log of accessibility between the end of year t and year t-1. We find small and weakly significant negative employment effects for manufacturing, consumer services and producer services. In the lower panel we look two-year differences and find slightly stronger negative employment effects for manufacturing and service sectors.

Figure 1: Changes in postcode-sector employment accessibility resulting from transport improvements

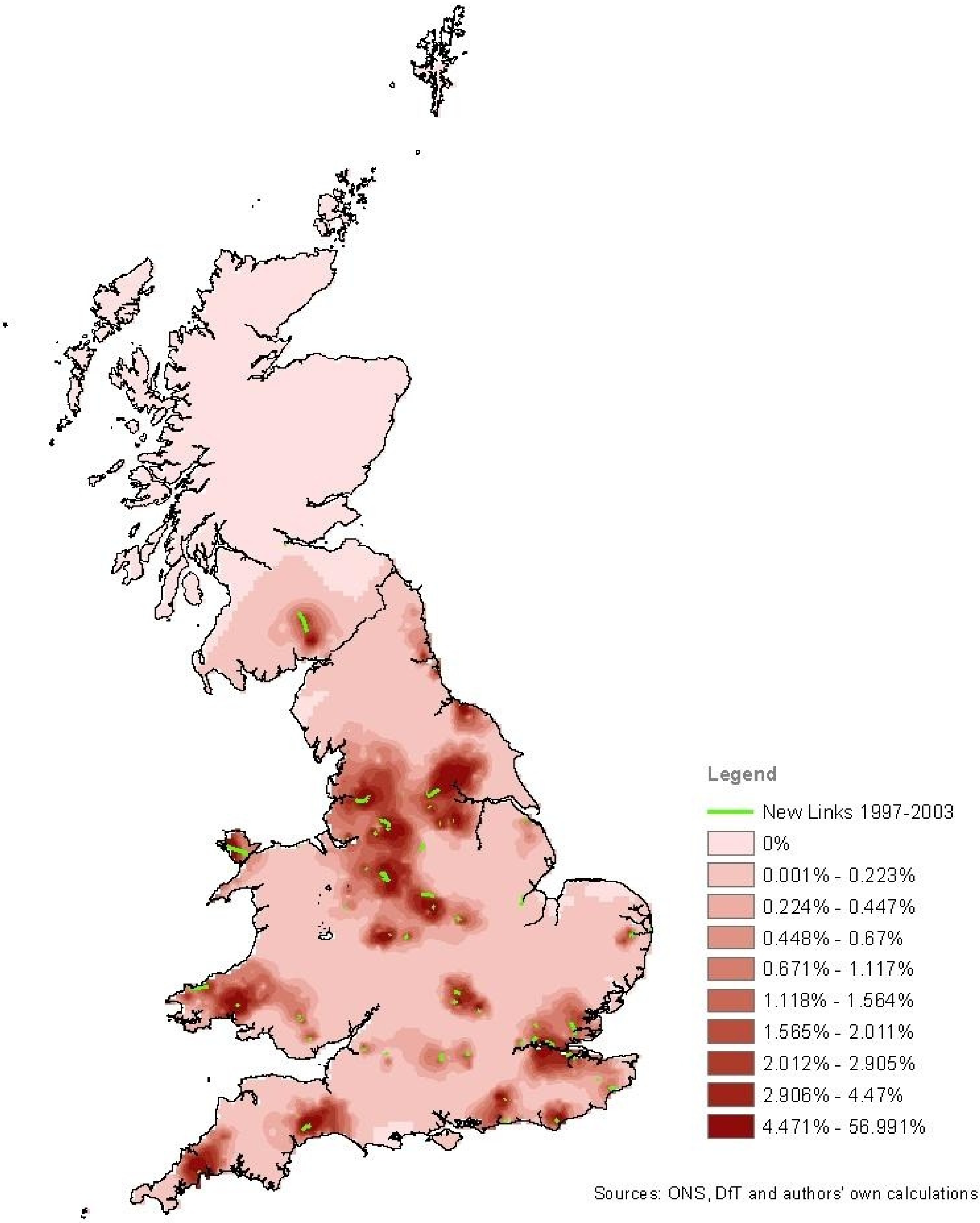

Table 2. *Local Unit employment and employment accessibility by road*

1 year diff	AGRI	MANU	CONST	CONS SERV	PROD SERV	OTHER
Coef.	0.025	-0.056*	-0.027	-0.03*	-0.038*	-0.001
Std. Err.	0.024	0.032	0.041	0.018	0.021	0.024
N	371000	687000	634000	2710000	2370000	1360000
2 year diff	AGRI	MANU	CONST	CONS SERV	PROD SERV	OTHER
Coef.	0.007	-0.056*	-0.013	-0.042**	-0.074***	-0.039
Std. Err.	0.023	0.033	0.044	0.018	0.025	0.026
N	282000	478000	380000	1840000	1520000	948000

Results in Table 2 suggest that, in manufacturing and the service sectors, increased accessibility is related to decreases in employment in local units that stay put in the same postcode-sector. Next we estimate the overall effect of accessibility on local employment, including relocation and plant births and deaths, by looking at postcode-sector aggregate employment.

Table 3 reports results for postcode-sector aggregate employment. Industry sector division is now slightly different from Table 2. We report within estimates, first differenced estimates and estimates based on long differences from 1998 to 2004. All specifications include controls for distance to the nearest transport improvement, distance to other transport facilities (rail stations, motorway junctions, ports and airports) and an aggregated measure of skills in the residential population (NVQ Level 4+). The point estimates in Table 3 are positive for all sectors in all the specifications and some of the coefficients are statistically significant.

Table 4 reports results on the number of plants. As in Table 3, we get positive coefficients for all sectors and some of them are statistically significant.

Table 5 reports results on employment and local unit count using long differenced data and a discrete treatment variable. Moreover, we use three different distance band (10kmk, 30km and 50km to road improvements). The sample includes postcode sectors that belonged to the top quartile or bottom quartile of accessibility changes between 1998 and 2004. The estimates are the coefficients of a dummy variable for belonging to the top quartile. We find positive and significant effects with the 10km distance band, but the estimates become insignificant when we use broader distance bands.

Table 3. *Postcode sector employment and employment accessibility by road (30km distance band)*

Within estimates						
	MANU	CONST	C SERV	TRANS	P SERV	OTHER
Coef.	0.496	0.935***	0.529*	0.544	0.863**	0.91**

Std. Err.	0.348	0.3	0.318	0.352	0.342	0.379
N	46215	47007	50179	45612	49747	49621
First differenced estimates						
Coef.	0.747**	0.383	0.536	0.389	0.345	0.58*
Std. Err.	0.294	0.288	0.345	0.336	0.328	0.313
N	38657	39381	42305	38057	41893	41915
Long difference 1998 - 2004						
Coef.	0.119	0.992**	0.466	0.997**	0.632	0.917*
Std. Err.	0.524	0.416	0.466	0.422	0.502	0.516
N	5879	5966	6469	5765	6431	6413

Table 4. *Postcode sector number of plants and employment accessibility by road*

Within estimates						
	MANU	CONST	C SERV	TRANS	P SERV	OTHER
Coef.	0.499**	0.645***	0.383	0.423**	0.508*	0.597**
Std. Err.	0.201	0.198	0.26	0.195	0.261	0.285
N	46238	47027	50187	45625	49770	49632
First differenced estimates						
Coef.	0.432***	0.433**	0.42*	0.473***	0.118	0.39*
Std. Err.	0.16	0.207	0.234	0.178	0.216	0.224
N	38677	39397	42313	38067	41915	41925
Long difference 1998 - 2004						
Coef.	0.298	0.767***	0.433	0.367	0.473	0.689*
Std. Err.	0.275	0.259	0.359	0.285	0.384	0.384
N	5882	5970	6470	5766	6434	6413

Table 5. *Postcode sector number of plants and employment accessibility by road, long differences and discrete treatment variable (top vs. bottom quartile)*

Distance band	10km	30km	50km
Employment	0.149**	-0.001	-0.007
	0.072	0.056	0.060
Number of plants	0.161***	0.027	0.034
	0.056	0.044	0.048
N	1561	3458	4239

4.3. Total Factor Productivity

Results from the Reporting Unit production function regressions are reported in Table 6. All models control for capital and labour and include year variables. The dependent variable is value-added and the table reports only coefficient on employment accessibility and its standard error. All variables are in natural logarithms, so the coefficients show the elasticity of value-added with respect to accessibility. Because the regressions control for capital and labour, the coefficient estimates correspond to the effect of accessibility on Total Factor Productivity. All specifications include controls for distance to the nearest transport improvement, distance to other transport facilities (rail stations, motorway junctions, ports and airports) and an aggregated measure of skills in the residential population. The sample is based on a panel of Reporting Units with a stable Local Unit structure. All specifications include stable firm fixed effects. A firm with a change in plant locations is treated as a new observation. We report the estimates for manufacturing, producer services and consumer services using a sample within 30km of the transport sites.

The point estimates in Table 6 indicate elasticities of 0.20 for consumer, 0.13 for producer services and -0.19 for manufacturing, but none of the estimates is statistically significant. The standard error are high relative to the effect that is typically found in cross-sectional agglomeration studies, which generally report elasticities in the 0.04-0.10 range. This suggests that the methodology needs to be refined to be able to test whether the elasticities found in other studies hold with panel data and a route optimization based accessibility measure.

Table 6*. Total Factor Productivity and employment accessibility by road, stable structure reporting unit TFP*

1 year diff	MANU	CONS SERV	PROD SERV
Coef.	-0.192	0.196	0.134
Std. Err.	0.128	0.213	0.168
N	21961	14669	7371

Table 6 showed Total Factor Productivity changes for a sample of incumbent firms that were established before the transport improvements took place and remained in situ until after. They are (necessarily) based on a highly selected sample of firms. These estimates could also miss out on productivity changes that occur at the local level due to entry, exit and relocation of plants and firms.

In Tables 7 and 8 we implement the two-step estimator described in Section 2[3]. We first estimate postcode-sector productivity effects for the pre and post improvement periods (year 1998 and year 2004) separately, using all Local Units from all Reporting Units in each year, whether or not they appear in our sample in *both* the pre and post periods. We then regress these estimated productivity effects on the accessibility variable, whilst controlling for postcode-sector fixed effects and other area-level control variables (interacted with a post-period dummy). In this two-period setup, this is identical to regressing the postcode-sector changes in productivity on the postcode sector changes in accessibility. In Table 7 we use the change in log of accessibility as the treatment. In Table 8 we use a discrete accessibility variable (top vs. bottom quartile of accessibility change) in order reduce potential measurement issues. Moreover, postcode-sectors in the top and bottom quartiles are geographically separated, and hence potential spillovers between neighbouring postcode-sectors do not affect the estimates. All specifications include controls for distance to the nearest transport improvement, distance to other transport facilities (rail stations, motorway junctions, ports and airports) and an aggregated measure of skills in the residential population.

In Table 7, we do not find significant association between changes in Total Factor Productivity and changes in employment accessibility, using the sample within 50km, 30km and 10km of the sites. Overall, the estimates are highly imprecise. The precision is improved in Table 8, when we switch to using top and bottom quartiles of changes in employment accessibility. Within 10km of the sites the coefficients are insignificant. For the 30 and 50km distance bands we get positive signs. In the upper panel using employment based apportioning of value added and capital to local units (plants) the estimates are highly significant even when we allow for sector specific returns to capital and labour in the first step regression. With common returns for all industries (in other words, estimating a single coefficient for the inputs for all industries) in the first step regressions, the coefficients are significant at the 10 percent level. However, they become insignificant once we use sector specific returns to capital and labour and use weighted regression.

Table 7. *Total Factor Productivity and employment accessibility by road, 2 step postcode sector TFP models*

Panel A: Valued Added and Capital apportioned based on employment			
Distance band	10km	30km	50km
Common returns	0.021	0.153	0.222
	0.188	0.185	0.181
Sector specific returns	-0.385	-0.219	-0.116

[3] In the first stage we estimate a standard firm-level productivity equation, as explained in Section 2.2. These results are not reported, but available upon request from the authors.

	0.304	0.288	0.283
Panel B: Valued Added and Capital apportioned equally and regressions weighted by employment			
Distance band	10km	30km	50km
Common returns	-0.045	-0.024	0.028
	0.32	0.303	0.299
Sector specific returns	-0.202	-0.359	-0.198
	0.615	0.57	0.556
Sample size (Pcsects)	2732	5820	7199

Table 8. *Total Factor Productivity and employment accessibility by road, 2 step postcode sector TFP models; top and bottom quartile changes*

Panel A: Valued Added and Capital apportioned based on employment			
Distance band	10km	30km	50km
Common returns	0.031	0.072***	0.073***
	0.021	0.015	0.013
Sector specific returns	0.024	0.057***	0.041***
	0.024	0.017	0.015
Panel B: Valued Added and Capital apportioned equally and regressions weighted by employment			
Distance band	10km	30km	50km
Common returns	-0.024	0.050*	0.046*
	0.044	0.028	0.025
Sector specific returns	-0.032	0.032	0.038
	0.044	0.028	0.024
Sample size (Pcsects)	1396	3103	4105

We also looked at employment accessibility effects on labour productivity (value-added/employment). We do not report these results in detail, because they are almost identical to those in Table 5 and 6. We argue that there are considerable theoretical advantages in using Total Factor Productivity, because labour productivity is sensitive to changes in capital intensity. In the present context, however, it evidently makes no difference whether we look at effects on Total Factor Productivity or Labour Productivity.

5. Conclusions

This paper uses a novel methodology in order to asses the productivity and employment effects from transport improvements at a very detailed geographic scale. We construct employment accessibility changes at the postcode-sector level using simple GIS network analysis combined with the register of local business employment (IDBR). These accessibility indices are linked to local units (plants) in the Annual Respondents Database (ARD) for the analysis of employment and productivity.

Overall, when we examine the combined effect of all major road transport improvements between 1998 and 2003 with firm level data focusing on firms and plants that remain in situ before and after the opening of new stretches of road, we find insignificant effects on the employment and productivity of firms. When we examine postcode sector level employment allowing for employment effects through firm mobility, start-ups and closures, we find consistently positive employment effects that are statistically significant for most sectors.

However, at face value, the results do not sit comfortably with common-sense notions of the benefits of transport improvements and the evident willingness to pay for travel time savings that have been demonstrated in the transport evaluation literature. However, it should be noted that we are not measuring productivity improvements of firms which necessarily make direct use of improved transport links, but rather the exposure of firms to accessibility improvements. Our methods will only detect the direct benefits of travel time savings to the extent that these are correlated with accessibility changes.

Some extensions to the methods and refinements will be considered in future analysis. We have not dealt explicitly with the timing of events in such a way that would allow for anticipatory effects or long time delays in impacts, or that would detect short run changes in time trends (rather than levels) of productivity. Future work will evaluate the structure of the accessibility indices e.g. using residential population rather than workplace based employment and experimenting with other assumptions about transport costs and travel speeds on the road network.

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Appendix A: Data

As discussed in the text, our source of firm data is the Annual Respondents Database (ARD). The Interdepartmental Business Register/Business Structure Database (IDBR/BSD) is used to construct measures of employment accessibility. Addresses of businesses in the IDBR/BSD are compiled using a combination of tax and VAT records. The IDBR has been operating since 1994 but service sector firms are only included from 1997 onwards. Measures of skills are taken from the Labour Force Survey (LFS). The source for transport networks is described in the text.

Annual Respondents Database

Value added and capital stock need to be deflated and to do this we use sectoral value added and inputs deflators from EU KLEMS "Growth and Productivity Accounts: March 2008 Release". Capital is measured with the perpetual inventory method. Labour is number of employees.

The most disaggregated level at which the ARD provides information on value added is the Reporting Unit level. We refer to Reporting Units as firms. Reporting Units can operate with one or more Local Units. We refer to these Local Units as plants and refer to firms with only one plant as singletons; firms with more than one plant as multi-plant firms. For each plant, we know the sector of activity, employment and exact location (post code).

Reporting Unit balance sheet information comes from the Annual Business Inquiry where each year only a fraction of the active Reporting Units is sampled. The first two columns of the table below (A.1) report for the years 1997-2004 the number of unique firms in the population and the number of unique firms sampled. The third reports the number of unique reporting units that can be used to estimate the production function. We need the firm to have in that year non missing value added, employment and capital. Then we need to have information on Local Units, from which the firm location is derived.

Table A1: Unique Reporting Units in the ARD

	Pop.	Sampled	Estimation sample
Total	2,993,514	273,831	182,794

Appendix B: Additional transport and skills control variables

Skills variables are derived from the Labour Force Survey, aggregated to Local Authority District level according to place of survey respondents residence. We use the proportion of the working age population with NVQ Level 4+, qualifications (which includes HNDs, First Degrees, Higher Degrees and similar qualifications). To obtain skills measures that vary by postcode-sector level, we use a similar procedure to that described above for urbanisation. The effective skilled share at Level 4+ for a given postcode sector *i* in a given year is calculated by averaging the contemporaneous skilled share in nearby Local Authorities, using an inverse-distance weighting sequence. This sequence applies a weight of $d_{ij}^{-1}\sum_{j} d_{ij}^{-1}$ to the skilled share in Local Authority *j*, where d_{ij} is the distance between the centroids of postcode sector *i* and Local Authority *j*. Note that these weights sum to 1. Postcode sector *i* is therefore assigned a weighted *average* of the skilled share in neighbouring Local Authorities, with nearest LAs receiving higher weights than those further away. The equation for the Level 4+ skilled share is thus: $S_i = \sum_{j \in D} \left(L4share_j \times d_{ij}^{-1} \times \sum_{j \in D} d_{ij}^{-1} \right)$ where *D* is the set of Local Authorities within 20km of postcode sector *i*. A plant (local unit) in the ARD is assigned skilled shares for the postcode sector in which it is located. Again, Appendix B details the treatment of multi-plant firms.

Some regression specifications include straight line distances to transport infrastructure nodes. The set of transport infrastructure nodes were derived from various sources: postcodes of passenger airports with international links obtained from http://www.ukairportguide.co.uk/; full access motorway junctions extracted from Ordnance Survey Strategic mapping data; rail station postcodes provided by the Department of Transport; sea port postcodes from UK Major Ports Group (http://www.ukmajorports.org.uk/). All these transport nodes were converted to point features in GIS software (ArcGIS), and straight line distances computed from each GB postcode sector to the nearest of each type of transport node feature (airport, Motorway junction, rail station, port). The figure below shows the locations of these transport nodes for each type of transport. These transport variables clearly best capture the ease of access to the transport links between rather than within locations.