"Transport improvements, agglomeration economies and city productivity: did commuter trains raise nineteenth century British wages?"

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Abstract

“New economic geography” finds that the city agglomeration productivity effect comes not only from the size of the city itself, but from the size of its hinterland: people who commute contribute to agglomeration economies. The nineteenth century saw the rise of railways and other transport improvements, and thus made it possible for the first time to live and work in separate places. Did this lead to a rise in commuting? And if so, did this lead to a rise in productivity? We find that the size of a city’s hinterland had no effect on productivity in the nineteenth century. The cost of train travel, relative to earnings, was too high for all but the very well-to-do to commute by train daily. But by the first decade of the twentieth century things had changed: the fall in train prices relative to earnings, and the rise of convenient and very low cost trams meant that commuting become economically important for the first time. The productivity effect was real, but lower than is found in Britain today, probably reflecting the relative fall in the cost of commuting in the last one hundred years. Nevertheless, we estimate that commuting raised urban wages by around 14%, and GDP in England and Wales by around 8%. This is in addition to earlier social savings estimates, and imply that railways were worth around 14% of GDP by 1906.

Setting the scene: nineteenth century Britain

Nineteenth century Britain was distinctive in its overall wealth, its highly productive capitalist agriculture, its wholehearted adoption of free trade, its large scale industrial and service sectors, and its degree of urbanization. These factors are interlocking, and connected with the quality of domestic, international and foreign transport.

Britain was unique in the low proportion of workers in agriculture – 25 percentage points lower than the European average at any given level of development. Industrial and service labour force shares were correspondingly higher. Higher incomes per head in any given time and the lower proportion of workers in agriculture at any income level together made for a very non-agricultural nation. Indeed, Britain's 1840 agricultural share of the labour force was not reached in France and Germany until after the second world war (Crafts 1985). Whilst it is possible for a country to be industrialised but not urbanized if industry was dispersed, this was not the case: Britain was uniquely urbanized, with Britons 50% more likely to live in urban areas at any given income level than the French or Germans (Crafts and Harley 2002).

Urbanization involved an additional expense that must be covered by wages: the cost of conveying food and fuel into the town. For urbanization to occur, therefore, either cities must have had higher productivity, or the price of one or more factors of production must have been lower, or both. Just as today, no factor of production was cheaper in cities in the nineteenth century: indeed, both urban labour and urban land commanded a premium. It follows, therefore, that productivity in urban areas must have been sufficiently higher to cover the higher urban business rents and wages (which in turn covered higher urban residential rents, food and fuel costs, as well as compensating for any urban disamenities). Good transport could reduce but not eliminate the premium workers had to be paid to live in the city.

Britain was lucky in its innate transport situation: an island, surrounded by tolerably benign seas, and with no winter freezes. Boats require less infrastructure than other forms of transport. Similarly, there are many reasonably easy to navigate rivers, few of which are hard to bridge. Many domestic agricultural areas were near London (East Anglia, Kent, Sussex), and coal could easily be shipped from Newcastle. Britain was a pioneer in all of the major pre-railway transport technologies, such as turnpike roads and stagecoaches, and canals, as well as in the extensive use of coastal shipping. Pre-railway transport improvements not only allowed urbanization per se, but inland waterways in particular also allowed cities and industries to locate away from coasts when that was advantageous.

But however important pre-railway transport improvements may have been, it was the railways that dominated the increase in nineteenth century transport infrastructure. Track miles grew from nothing prior to 1830 to 6,000 miles by 1850, 15,000 miles by 1870 and 20,000 miles by 1913. From 1830 to 1870 the UK invested on average about 1.5 per cent of GDP in railways and the resulting railway capital stock equalled 30 per cent of GDP. The social rate of return on this investment was averaged 15 per cent (Hawke 1970). The invention of new technology led to massive levels of investment, fully justified by the social rate of return. The peak impact of railways on labour productivity growth was substantial but not overwhelming: 0.26 per cent per year (0.12 from capital-deepening, 0.14 from TFP growth) on a growth accounting basis (Crafts 2004). This represented about a fifth of total labour productivity growth at the time.

Theory

The classic way in which economic historians have assessed the impact of railways is termed "social savings". This approach was first used in the 1960s in the pioneering works of Fogel and Fishlow (Fishlow 1965, Fogel 1964). Their studies aimed to quantify the value of railways to the United States in 1890 and 1859, respectively. Put simply, the social saving from railways is the minimum additional amount that society would have to pay to do what the railways did, without them, that is, the cost of moving freight and passengers without trains. Social saving thus measures the fall in resources required to provide a given level of output. It is analogous to total factor productivity growth, since, under competitive conditions, TFP growth is equivalent to a fall in the cost of providing output. Thus social savings is a measure of the contribution of technology change to productivity growth (Foreman-Peck 1991).

Whilst social savings can be an effective means by which to measure the transport benefits of railways, it will understate the magnitude of the economic benefits of railways if the reductions in transport costs generated TFP spillovers. They could have done so in a number of ways. First, reductions in transport costs have potential implications for the location of industry. No longer do firms have to locate near to their raw materials, or to their customers. Rather, lower transport costs allow them to locate in any place that is advantageous to them. Perhaps the extreme example of this is the Lancashire cotton industry, which used raw cotton from the American south, from India and from Egypt, to produce cotton goods, the vast majority of which were then exported. This industry could not have existed without effective international, domestic and foreign transport. That said, recent work by Crafts and Mulatu shows that railway had very little effect on the location of industry within Britain, which was determined instead during the canal era (Crafts and Mulatu 2006).

New economic geography has shown that the spatial concentration of production leads to agglomeration benefits via increased internal and/or external economies of scale (Marshall 1920, Venables 1996). Thus, firms may gain from proximity to their suppliers and/or customers, from increasing plant size or from technological externalities (Jacobs 1970). Another potential advantage of agglomeration is that thick labour markets permits better matching of skill demands and supplies and can also encourage the development of a pool of expertise.

In this context transport improvements matter in two senses. They can permit the existence of cities, by allowing unadulterated food to reach cities cheaply and reliably. This was largely achieved prior to the invention of the railway, by canals and coastal shipping. Second, and more interestingly in this context, railways permit commuting. The determinant of economies of scale is not the number of people who *live* in a city, but the number of people who can or do *work* in the city. As such, commuters into a city can have just as large an effect on that city's productivity as those who live in the city itself. Recent work has found that for the UK today the population within an 80 minute commute of a city has a positive effect on the city's productivity (Rice, et al. 2006). A transport improvement that increases the number of commuters into a city will have a TFP spillover that would not be captured by traditional cost-benefit analysis, such as social savings. This paper addresses exactly this issue.

These new economic geography results sit well with intuitions drawn from the broader new growth economics literature. Howitt and Aghion note, for example, that falling transport costs increase the size of the market, increasing the potential reward to successful entrepreneurs, so stimulating research and development. As such, falling transport costs can raise the rate of economic growth. In addition, Aghion and Schankerman have shown that transport improvements can raise economy-wide productivity by integrating markets and forcing less-efficient producers to exit. Finally, Aghion et al has shown that when falling transport costs integrate markets and raise the level of competition, managers (agents) have less ability to be "sleepy", as principals are better able to judge the effort levels of their agents. These factors could be potentially important for nineteenth century Britain, but lie outside the scope of this paper (Aghion, et al. 1997, Aghion and Schankerman 2004, Howitt and Aghion 1998).

The spillover effect of transport improvements on urban productivity via commuting can best be seen diagrammatically, using diagrams based on the work of Rice, Venable and Pattachini (Rice, et al. 2006). Let us first characterise the position without any spillover effects, that is, when the city wage premium is invariant in the number of workers. This is shown as W on the y-axis of figure 1. For diagrammatic simplicity we assume that there are equal numbers of workers at each distance from the city centre, so that the x-axis represents the distance from the city centre, represented by the origin, and the number of people at different distances from the city centre. Line C represents the original cost of commuting. It slopes upwards, reflecting the fact that generalised commuting costs, that is costs in terms both of time and money, increase as the distance travelled increases. We assume that these costs are linear in distance, the slope of line C gives the cost per unit of distance. Given an urban wage premium of W, people living up to a distance X from the town centre will find it worthwhile to commute into the town: the wage premium will be at least equal to the cost of commuting. Imagine now that technological change reduces the cost of commuting from C to C'. Those who are already commuting will gain an amount equal to α (this may manifest itself in higher residential rents if land is the scarce urban resource). In addition, those who live between X and X' from the city centre will now find it worth commuting into the town. The rise in their wages, net of the additional transport costs, is given by β, and α + β represent the benefit captured in both traditional cost benefit analysis and by social saving calculations.

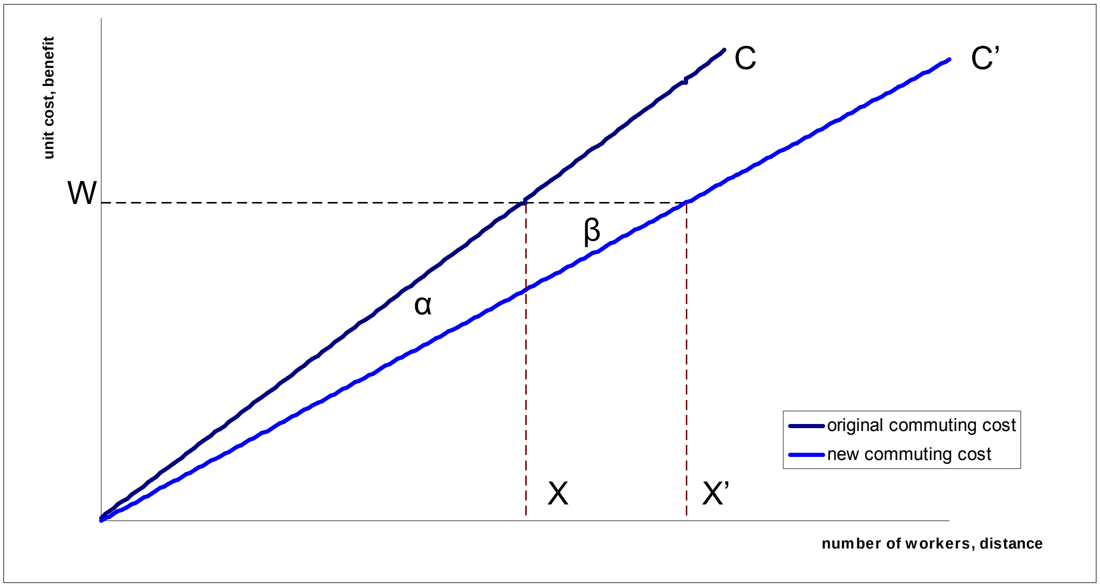

Figure 1

The presence of agglomeration economies changes this story, with the new situation given in figure 2. Since the number of workers in the city has increased by the number of people living between X and X', productivity in the city will increase by the elasticity of productivity with respect to agglomeration, multiplied by the number of workers living between X and X'. The responsiveness of productivity to population is given by the wage gap curve, which gives the relationship between population and the urban wage premium. This exhibits diminishing marginal returns to agglomeration: were there to be increasing returns we would have a corner solution: either everyone would work in one place if the agglomeration economies exceeded commuting costs for all of the population working in one place, or no-one would work in the same place as anyone else, if commuting costs were sufficiently high. Given the rise in productivity from population X'-X now working in the city, wages will rise along the wage gap schedule, and the cycle repeats itself until it reaches a new equilibrium shown on the diagram as wage premium W'. At the new equilibrium an additional group of workers, those living between X' and X'' now find it efficient to work in the city: the new (higher) wage is at least equal to the new (lower) commuting cost. The result is a net agglomeration externality equal to δ, over and above the transport benefit α + β.

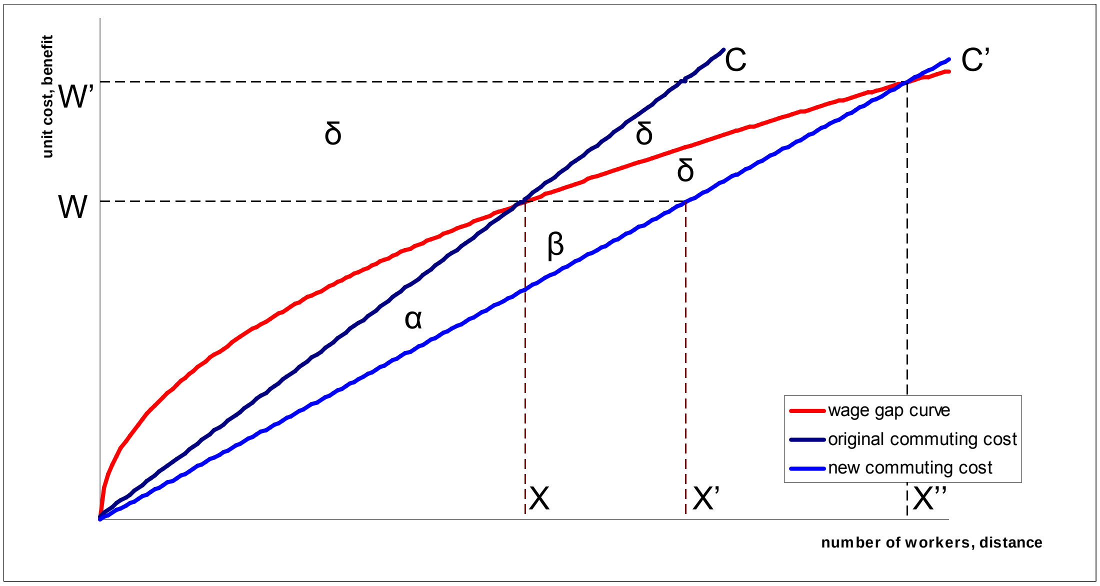

Figure 2

For nineteenth century Britain, we can ask whether it is the case that when transport costs were high at the start of the century, people living between X and X'' did not commute into the city, and so did not have an effect on city productivity, whereas when transport costs were low at the end of the century, people living between X and X'' did commute into the city, and did have an effect on city productivity. We can then go on to quantify the effect on urban wages, and so on economy-wide GDP. This externality is additional to the benefits captured either by convention transport cost-benefit analysis or by social saving estimates of the value of railways.

Data construction

In order to test whether agglomeration economies existed in the nineteenth and early twentieth century we need to know wages in particular places, and the populations at and nearby those places. We construct the necessary data for three points in time: one immediately prior to the advent of the railway (the 1830s), and two during the railway era – 1868 and 1906.

Wage data

We use bricklayer's wages for a number of well-known reasons. Bricklaying is a well-defined job that is readily found across Britain, holding out the possibility of a reasonable sample size. We do not claim that bricklayers productivity varied from place to place, but rather that bricklayers wages in any given locality were set with respect to the wages of other local semi-skilled workers in occupations whose productivity might well have varied with city size.

The wage data for the pre-railway era were originally constructed by Greg Clark (Clark 2005). Clark's dataset has three types of bricklayers, those described as bricklayers with assistants, those described simply as bricklayers, and those described as bricklayers' labourers. The wages of each group are very different, and we restrict ourselves to those simply described as bricklayers. For the earliest period wage observations are relatively scarce, with observations for no more than nine places for any individual year in the 1830s. By combining the data for all of the 1830s we raise the number of observations to 58, covering 22 towns in total. We use Clark's data again for 1868, a year selected simply because Clark has data for more towns – 28 – in that year than in any other in the 1860s. For 1906 we use the British government's Enquiry into Earnings, which yields observations for 184 towns (Earnings and Hours Enquiry 1909).

Population data

As is well known, the UK Census of Population was taken every decade from 1801 onwards. The Census records population by parish, and these records have been computerised by Humphrey Southall and made available via the ESRC/Essex data archive. The data have been computerised in four sections, 1801-1851, 1861-1871, 1881-1891 and 1901-1911. The list of parishes are consistent within each of the four sections, but not across them. Thus there are 16,400 parishes listed for 1801-1851, 16,027 for 1861-1871, 15,115 for 1881-1891 and 17,628 for 1901-11. In each case the parish is fully-described, with county, district, sub-district and parish name given. We can interpolate population between years where necessary, so that we know, with reasonable accuracy, the population in every parish in every year.

Location data

If we are to test the extent to which agglomeration raised productivity and so wages, we need to know the location of each of the parishes for which we have population data. Greg Clark has found the location of 15,095 parishes in England and Wales (Clark 1998). These are expressed in latitude and longitude, and give the location to the nearest kilometre. The description of the parish is not as detailed as in the Southall dataset, consisting simply of the name of the county and the parish concerned, rather than including the district and sub-district.

Since both the Southall and Clark datasets use the parish as the unit of analysis, it proved feasible to find the locations of each of the four Southall sets of parishes in the Clark dataset. Sometimes this was straightforward: Ampthill in the county of Bedfordshire, for example, appears once in each of the datasets and could be matched by computer. Over one third of the Southall population data places could be matched automatically to the Clark location data. The remainder needed at least some level of manual intervention. Bedford, the county town of Bedfordshire can serve as an example. The Clark dataset simply has "Bedfordshire Bedford" as an observation. The Southall datasets for 1801-1851, 1861-1871 and 1901-1911 divide Bedford into nine parts, for example, "Bedford Western Ward St Peter". Since we only have one location for Bedford, all nine subdivisions of Bedford are given the same latitude and longitude. This obviously introduces a slight inaccuracy, in that the nine parishes would not all have been in exactly the same place, but the error is likely to be small.

The Southall data for 1881-91 has no parish including the word "Bedford" in the title. In this case, however, there were 23 sub-districts of either "Bedford and Cardington" or "Bedford and Kempston". Some of those twenty three – such as Cople – could be matched to parishes of the same name and county in the Clark location dataset, and were assigned the specific latitude and longitude for that parish. The remainder – generally with names such as "St Peter (W)" were assumed to be in Bedford itself, and thus given the latitude and longitude of Bedford.

Finally, some of the places listed in Southall's dataset could not be traced in the Clark dataset. The locations of these places were found using the modern day Ordnance Survey Gazetteer of places, which gives the latitude and longitude for the currently 36,633 inhabited places in England and Wales.

The wage data, in contrast, is given by town rather than by parish. Very often towns have clear parishes associated with them – as noted, Clark has a single location for all of the parishes in Bedford. In other cases, such as Barrow-in-Furness, the name of the town will not readily link to the name of the parish (in this case Dalton-in-Furness). In these cases the Ordnance Survey Gazetteer was used to find the location of the town. Finally, of course, there is London, for which there is no definitive centre. In this case, the centre was placed at Holborn, and arbitrary but reasonable definition. It would be equally plausible to claim that the centre of London was Westminster, five kilometres south-west, or in the City of London, a little over two kilometres further east, but such a change would not be expected to alter the results in any significant manner.

We need to be aware of a number of issues. First, the population of each parish has been assigned to a single point in space, even though not everyone in that parish would necessarily have lived in exactly that place. We have, therefore, a degree of "clumping" of the population. That said, we should not overstate the magnitude of this problem: the population is assigned to around 16,000 parishes, so the vast majority of clumps are small in scale. Second, the location of those clumps is, within a limited extent, sometimes arbitrary. For small parishes the location will be unambiguously defined. But for larger parishes there is a degree of discretion, and we should be aware that it would be possible to have selected a slightly different latitude and longitude. That said, geographically larger parishes are generally rural, and account for a relatively limited share of the British population. Finally, as we have noted, it would also be possible to argue that the wage observations for London in particular, were in fact drawn from a location slightly different to that chosen for this exercise.

Having assigned all of the population of England and Wales to parishes, and having assigned a latitude and longitude to each of the parishes, we are now in a position to say how many people lived at any given latitude or longitude. We can also use Pythagoras' theorem to calculate the number of people living within *x* kilometres of each place. In using Pythagoras' theorem we make two implicit assumptions. The first is that the curvature of the earth is too small to be an issue. Since we are interested in the number of people living within – say – 60 km of a place that criteria is satisfied. Second, we are assuming that people can, give or take, travel in a straight line. With the exception of one or two rivers (most obviously the Humber and Severn) Britain has no geological boundaries, and, of course, no political boundaries to prevent movement. As a result Pythagoras' theorem seems an effective way of working out the distance between two places.

We therefore take each place for which we have a wage observation, and ask which of the approximately 16,000 other places in Britain lay within x kilometres of our wage observation in that year. We then sum the populations of the places lying with x kilometres. The natural logarithm of this number forms the basis of our right hand side variables.

It would be mechanically straightforward to work out the number of people living in relatively narrow bands, such as 0-1, 1-2, 3-4, 59-60 etc kilometres away. This would, however, be inappropriate given the way in which the data are constructed. As we have noted, the populations of places are defined as being at single points. Thus, for 1906 over 100,000 people are defined as living at the specific location to which Liverpool is assigned, and that point is exactly 49.5 kilometres away from the specific location to which Manchester is assigned. But it would in reality be absurd to imagine that there were over 100,000 people exactly 49.5km from Manchester. It is more plausible to believe that the 100,000 people living in Liverpool lived, say, 45-55km from the centre of Manchester, and, say, 40-60km from the nearest and furthest parts of Manchester. Because of this, and following the example of Rice and Venables (2004), we group the data into geographical bands, as follows. Our first band is a plausible definition of the town itself. This is an area 6km from the wage observation. In essence we are trying to include all of those people who could have walked to work. Next, we define two "nearby" bands, those living 7-18 km from the centre and those living 19-30 km from the centre. [1] People living in these distances could not easily have worked in the town itself without some form of transport. By 1906, subject to the presence of a reasonable train line, a person could commute around 30 km in an hour, plus an allowance for walking to or from the train station at either end, to give a total journey time of around 80 minutes. This equates to the maximum economically significant

[1] Where we have only a few observations it is necessary to merge these two categories, owing to issues of multicollinearity.

commuting time found in modern day studies. Thus our priors are that, in the pre-railway era, only the population within 6 km will be a statistically significant determinant of city productivity: you had to live in the city to work there. As time goes on, and the railway network gets more extensive, trains become more comfortable, more frequent and less expensive relative to earnings, commuting is likely to become more important, and its effect on productivity may be statistically significant. That said, we would not expect the co-efficient on the commuting population to match or exceed that on the resident population. We also include an additional, more distant band, 31-60km away. Since the commuting time from this distance would generally exceed that found to be economically significant today, we do not expect that the co-efficient on people living over 30 km will be significant at any of the dates used considered in this paper.

Results

In keeping with the literature in this area, we use the natural logarithm of wages as our left hand side variable, and the natural logarithm of population in different bands as our right hand side variable. For the pre-railway era we use all of Clark's data for 1831-40 (with dummy variables for each year), whilst for the other regressions we are able to limit ourselves to data for a single year. For the 1830s and 1868, where the sample sizes are much smaller, we merge the two potentially commutable bands 7-18 and 19-30 km into a single category, 7-30 km. For 1906 we have significantly more data and are able to distinguish between these two categories. It might be claimed that there is an issue of causality here: are wages high in cities because lots of people live there, or do lots of people move to cities because wages are innately high in that location? Against that, it is possible to argue that this issue is less important than might be expected: money wages were higher in cities, but so was the cost of living. We know that in a market economy rents go to the scarce factor of production, and in cities the scarce factor was not labour, but land. The final recipient of higher urban wages was not primarily the worker, but the worker's landlord: the streets of London were paved with gold only if you owned property. For that reason it is not clear that reverse causality is an issue, nevertheless we use IV as well as OLS to cover any issues in this area. As is common in this literature, we use the 1841 population as an instrument for later years. This census is considered to be more reliable than earlier censuses, and therefore we prefer it to, say, 1801. Since 1841 is after 1831-40, we do not use IV estimation for that regression. It is worth nothing that both OLS and IV give the same results for 1868 and 1906, so the absence of IV estimates for the 1830s is unlikely to be critical. For 1868 and 1906 we use two different versions of the instrument. First, we instrument only on 1841 population in the town itself, that is, up to 6km away. Second, we include as instruments the 1841 own population, and the 1841 hinterland population – 7-30km away. The different specifications give slightly different results for 1906, as the table shows.

Table 1 about here

Table 1 shows that the population of the town itself is always a strongly significant predictor of wages in that town, but that nearby population matters only in 1906. In that year doubling the nearby population would raise city productivity by a little over 2-2.5%, where nearby is defined as 6-30km in the OLS and IV own population specifications, and 6-18km in the IV own and hinterland population specification. 2% or so is considerably lower than the equivalent figures found for the UK today, which suggest a productivity elasticity with respect to population within commuting distances of 3-8%. This suggests that the extent or effect of commuting for a given time on productivity was considerably lower in 1906 than today, reflecting either the fact that whilst commuting was easier, cheaper and more comfortable in 1906 than in earlier times, it has become easier, cheaper and more comfortable still since then or that industrial structures and technologies offered fewer potential economies of scale then than now.

We can use these estimates to calculate the effect of commuting on aggregate GDP in 1906. As per figure 1, we interpret the statistically significant co-efficient on hinterland population as saying that the people living in these areas are now economically part of the city. The effect on urban wages can be estimated by taking the ratio of the population of the new definition of the city (that is, including its hinterland), to the population of the old definition of the city (that is, the population within 6km) and multiplying it by the elasticity of productivity with respect to population, which is estimated in the regression. This gives the effect of enhanced commuting opportunities on urban wages. Since this will have an effect only on urban wages, we convert the urban wage effect to a national wage effect by multiplying by the ratio of urban to all population.

Finally, we convert the wage premium to a GDP premium by multiplying by the ratio of labour income to national income. The results are given in table 2.

Table 2 about here

Table 2 shows that the effect on urban wages varies between 7.5% and 21%, depending on the specification used. Since Britain was an overwhelmingly urbanised country, the effect on average UK wages was relatively close to the effect on urban wages, and is estimated at between 6% and 17%. The effect on GDP is estimated at between 4.4% and 12%.

It is possible to argue that these figures both overstate and understate the true effect. If it were the case that, without any possibility of commuting all the people who commuted in 1906 would have lived in the centre of cities, then the true effect on productivity would be zero. Nevertheless, it is hard to make such a case. If commuting were simply allowing people to move out of the cities we might expect to see city populations fall. Instead we find that they rise (interestingly though, city populations do fall after 1918, suggesting that commuting possibilities may then have allowed people to move away from cities and into suburbia and surrounding, smaller, towns). Equally it is plausible to argue that non-urban wages may have risen as a direct result of new commuting opportunities. Britain is a relatively small country with a relatively mobile population. Insofar as urban wages rise, the possibility of migration can lead to rural wages rising too. That commuting opens up the possibility of city wages without the full horrors of city disamenities can further facilitate migration, reducing the (over)supply of rural labour, and so raising rural wages. Any such effect would not be captured in this calculation. Furthermore, this calculation assumes that only wages rise, and that the returns to capital and land are unaffected. It is easy to imagine that higher productivity would increase the returns to other factors of production, particularly to urban land. Such an effect would also not be captured in this calculation.

Commuting increased the agglomeration effect of cities by 1906. A plausible estimate of the magnitude of this effect is that it increased urban wages by around 14%, and economy-wide wages by around 11%, implying a rise in GDP in England and Wales of around 8%. These are large numbers: the social savings of railways at this time, in terms of the lower monetary costs of using trains over pre-rail methods, was around 3% of GDP, with a total saving, including the value of time saved by faster travel estimated at 6% on a consumer surplus basis (Leunig 2006). Adding an agglomeration externality of 8% more than doubles our estimate of the benefits of transport improvements to the economy in the early twentieth century.

Discussion

Given that there were approaching 15,000 miles of rails by 1868, three-quarters of the 1913 network, it is perhaps at first sight surprising that nearby population was of so little consequence in 1868. To understand this we need to realise that what matters is not whether the railway was built, but whether it was used. Here a number of statistics show that there was a long lag between the railway being constructed, and being used extensively. Whilst passenger rail miles increased by more than three-fold between 1848 and 1868, the figure for 1868 was still less than one-fifth of that for 1906. Furthermore, the increase in third class passenger numbers as the nineteenth century developed was even more dramatic: third class passenger miles rose more than eightfold between 1868 and 1906 (see table 1). Railways were not used extensively earlier on because the costs, in time and money were high. Average third class fares fell by around one half in nominal terms between 1870 and 1914, during which time working class wages rose by around one half. As such, rail travel was three-times as affordable in 1914 as in 1870. In addition, trains became faster over time, with average speeds rising from 23mph in 1870 to 28mph in 1910, so that the time as well as money costs fell in this period (Leunig 2006). At 10s per week the 1860s fare from a London suburb such as Barnet, 9 miles from the centre of London, was estimated by contemporaries to be ten-times as high as would be needed for trains to be of use to skilled blue collar workers. (Kellett 1979). Instead, commuters were more typically people with an income of £500 a year. For these people, commuting allowed them to live in more salubrious surroundings, while still receiving city centre wages. Commuting and suburbia can be seen as a "new good", the ultimate expression of which is to be found in the New Towns movement. As the century went on, the number of commuters increased. This was in part because falling fares and rising affluence reduced fares relative to income, allowing more people to choose to commute. Some firms offered an increasing range of half, and sometimes quarter rate fares designed to attract commuters. The Great Northern's use of half price fares in the 1880s to attract white collar workers to London suburbs such as Hornsey and Wood Green increased the number commuting by around 1,600. Although this number was significant relative to the population of Hornsey and Wood Green, it was a trivial number compared with the total London population (Kellett 1979). Even as late as 1901, only 132,000 people commuted into London on "cheap trains", and of those, only under 30,000 travelled on the famous 2d workman's fares. (Kellett 1979). The Royal Commission on London noted that the number of journeys per head was lower in London than in Paris, Berlin or New York – a third lower than the latter two (Royal Commission 1905). Railway companies were not, in the main, keen to encourage commuter traffic, with one railway company chairman remarking that satisfying the demand for commuting "would be all right if they [commuters] do it all day and all night, but unfortunately, it is only between such a short time that we have not the means of making a profit" (Henry Oakley, Chairman of the Great Central, 1894, quoted in (Kellett 1979)).

That public transport was of little consequence in getting workers to work prior to end of the century can be seen in other ways. An era in which factory workers walked to work requires that housing and factories were intermingled within towns, a pattern clearly manifest in any British city in this era.[2] Thus a liberal land use regime acted as a substitute for a transport system that was too expensive for workers to use on a daily basis, and back-to-back terraced housing and tenement blocks close to workplaces were a rational response to the high cost of transport relative to workers' wages.

At the end of the century, trams began to offer extensive local commuter transport, particularly in northern towns such as Manchester. The growth in trams was remarkable. There were essentially no trams prior to the 1870 Tramways Act, after which horse drawn trams emerged. Electric trams appeared from 1885 onwards, and by 1906 almost 90% of all trams were electric. Bagwell remarks that "Electric tramways provided the cheapest-ever form of mass transportation for urban residents" and the number of tram journeys rose 7 fold between 1886 and 1907, during which year a staggering 2.5 billion journeys were made by tram. (Bagwell 1974)

[2] See www.lancashire.gov.uk/environment/oldmap/ for contemporary maps.

That trams, buses and walking, rather than trains, were the primary means of getting to work even in London can be seen not only from the usage statistics that we have, but also from the pattern of population change in the South East in the nineteenth and twentieth centuries. Commuter trains allow people to live at a considerably greater distance from their place of work than do trams, buses and commuting on foot. Thus if commuter trains had been important, we would expect to find that the population of places near London would increase, perhaps even at the expense of London itself. In contrast, were trams and buses to be important, then we would expect to see London growing dramatically. This latter picture is indeed what we see for the nineteenth century, which saw the population of London growing from 2.3m in 1841 to 7.3m in 1911, with the working population increasing from 600,000 to 2.6 million. At the outbreak of the first world war London's share of the British population was at an all-time peak, 50% higher than a century before, and a quarter higher than its nadir in 1951. In contrast the share of the UK population living in Kent, Surrey and other parts of the south east fell back during the nineteenth century, before expanding in the twentieth century as medium-distance commuting became commonplace (Baines and Woods 2004). We can see this even in the railway's late nineteenth century heyday, by looking at the changing positions of London and East Anglia, given in table 3. In 1871 the population of East Anglia was around 30% of that of London, falling back to 20% by 1911. This migration was not sufficient to stabilise GDP per head, however, with East Anglian GDP per head relative to London falling from just over two-thirds of London's level to under one-half. In short, in this era East Anglia was a place to migrate from, not to commute from.

Table 3 about here

Nor was London unique in sucking workers out of surrounding areas: the nineteenth century was a period of massive and unprecedented urbanisation. Between 1841 and 1911 the English and Welsh population doubled, but rural areas grew only slightly. 3.3m were born in rural areas but left for other parts of the UK – some 40% of the rural population. Of those, 40% went to London, 30% to eight large northern industrial towns and textile districts, 20% to colliery districts, and just 10% to all other areas. In a largely deregulated economy with a primitive welfare state, limited transport and no building or planning restrictions, the result of economic change was migration to cities (Baines 1985).

Conclusion

We have provided evidence that commuting – as proxied by the hinterland population –affected urban productivity by 1906. This was not simply the coming of the railway: that had happened by 1868, when we find no such effect. Rather the railway had not only to exist, but to be affordable, in terms of the cost in time and money. But by 1906 the railway and the tram had opened up the possibility of travelling moderate distances to work on a regular basis. We find good evidence that population living up to 18km from the centre affected city centre wages, and some evidence that population as far away as 30km mattered. Modern day studies show that the population within 80 minutes commuting distance has a statistically significant effect on urban productivity, and it is plausible to see 18km as the furthest that could be travelled in that time by tram, and 30km as the furthest that could be travelled in that time by train, including an allowance for connections and walking at either end. In that sense these results are in line with modern studies. That said, the elasticity of productivity with respect to population a given journey time away are lower than for today. This suggests one of two things. Either changes in production techniques in the past century have increased scale economies, or the higher money and disamenity cost of travel in 1906 compared with today reduced the propensity to commute for journeys of any given duration. This would lower the co-efficient in that a population of a given size would translate into fewer commuters.

Although the elasticity of wages with respect to nearby population is smaller than found in current studies it was still significant. We estimate that the effect of commuting was to raise city wages by around 14%, economy-wide wages by about 11%, and GDP by around 8%. These are large numbers: previous estimates of the benefits, in terms of time and money, of railways are under 6% of GDP. Including the productivity externality more than doubles our overall estimate of the benefit of transport improvements to the UK economy, which now appears to have been around 14% by 1906. Railways and their urban counterparts may not have been indispensable, and the full benefits took many, many years to come about, but by 1906 they were of tremendous importance to the economy.

Table 1: Did nearby population affect wages?

	1831-40	1868			1906		
Instrument	None	None	1841 own population	1841 own & hinterland population	None	1841 own population	1841 own & hinterland population
Own population (0km < location < 6km from centre)	**0.11 ***** **(7.08)**	**0.11***** **(6.48)**	**0.11 ***** **(6.12)**	**0.11 ***** **(6.24)**	**0.045 ***** **(7.48)**	**0.037 ***** **(4.78)**	**0.040 ***** **(5.11)**
Nearby population band 1 (6km < location < 18km)					**0.020 **** **(2.62)**	**0.025 **** **(3.02)**	**0.023 *** **(2.42)**
Nearby population band 2 (18km < location < 30km)					**0.026 **** **(2.95)**	**0.024 **** **(2.73)**	0.014 (1.25)
Nearby population bands 1 and 2 combined (6km < location <30km)	0.014 (0.69)	-0.003 (-0.14)	0.000 (-0.02)	-0.007 (-0.30)			
Distant population (30km < location < 60km)	0.019 (0.83)	-0.008 (-0.32)	-0.008 (-0.33)	-0.019 (-0.75)	0.004 (0.45)	0.004 (0.43)	0.010 (1.05)
constant	-0.13 (-0.32)	0.67 (1.59)	0.68 (1.61)	0.89 (2.04)	0.99 *** (10.24)	1.04 *** (10.23)	1.08 *** (10.01)
F	9.2	21.5	20.0	19.9	55.5	46.8	37.2
Adj R2	0.63	0.70	0.69	0.69	0.54	0.54	0.53
Root MSE	0.01	0.09	0.09	0.09	0.08	0.08	0.08
Observations (Number of towns if different in parentheses)	58 (22)		28			184	
Note: railway mileage per capita (third class in parentheses)	0		123 (66)			367 (330)	
Source of wage data	Clark		Clark			1906 Enquiry	

Notes: LHS variable: ln(bricklayer's hourly wages); RHS variables: all in natural logs; 1831-40 Year dummies included but not reported
t-stats in parentheses, * = significant at 5%, **, 1%, *** 0.1%; Significant coefficients of interest highlighted in bold. Estimated using Stata 9.2

Table 2: The effect of agglomeration economies on wages and GDP: England and Wales in 1906

A	B	C	D	E	F	G	H	I
Regression	km included	ratio of new to old population	coefficient	effect on urban wages	urban/total population ratio	effect on E&W wages	labour share of GDP	effect on E&W GDP
OLS	6-30	9.25	2.35%	19.4%	81%	15.6%	72%	11.2%
1841 own	6-30	9.25	2.52%	20.8%	81%	16.8%	72%	12.1%
1841 own and hinterland	6-18	4.22	2.33%	7.5%	81%	6.1%	72%	4.4%

Notes:

A refers to the 1906 regressions reported in table 1
B gives the size of the hinterland now taken to be part of the city, given the possibility of commuting.
C is the ratio of the population of the new to old definitions of the city, that is, including hinterland to excluding hinterland
D are taken from table 1. Where there is more than one coefficient, a simple average is taken
E = (C-1) * D
F is taken from (Baines and Woods 2004), p. 44, taken in turn from the 1911 census
G = E * F
H is taken from (Feinstein 1972), p. T5 (earned income plus self-employed income divided by GDP)
I = G * H

Table 3: The relative position of East Anglia and London

	East Anglia / London	
	1871	1911
Population	29%	20%
GDP per head	68%	46%

Source: (Crafts 2005)

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