

Is Pennine England becoming more Polycentric or more Centripetal? An Analysis of Commuting Flows in a Transforming Industrial Region, 1981-2001

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Abstract

This paper examines census-derived commuting data for the world's earliest major urban-industrial region, now home to 10 million people. Owing its origins to water power from the Pennine rivers, this region now comprises many closely-spaced cities and towns whose distinct identities have been eroded through the loss of their local industrial specialisms and the long-term growth in mobility. It contains five of the city regions identified by 'The Northern Way', a policy initiative designed as part of the Labour government's 2004 Sustainable Cities Plan for stimulating agglomeration economies across the wider region, with a more polycentric structure being seen as a positive contribution to this development. The paper tests how far this part of Northern England may be evolving into a single polycentric mega-city region, using commuting data from the 1981, 1991 and 2001 Censuses. Two hypotheses are tested; namely, that there is increasing polycentricity within each of the five city regions and that there is increasing linkage between the five city regions. With gravity modelling removing the effects of generic reductions in distance deterrence, evidence is found of trends towards greater polycentricity at both these scales of analysis, albeit modest in scale: there has been some reduction in the five cities' attraction of commuters living in the other parts of their city regions and the boundaries between the city regions have become somewhat more permeable over time.

Keywords: Polycentricity, multi-scalar, urbanisation, commuting, Pennine England

JEL Classifications: R23, R12, R14, R58

Introduction

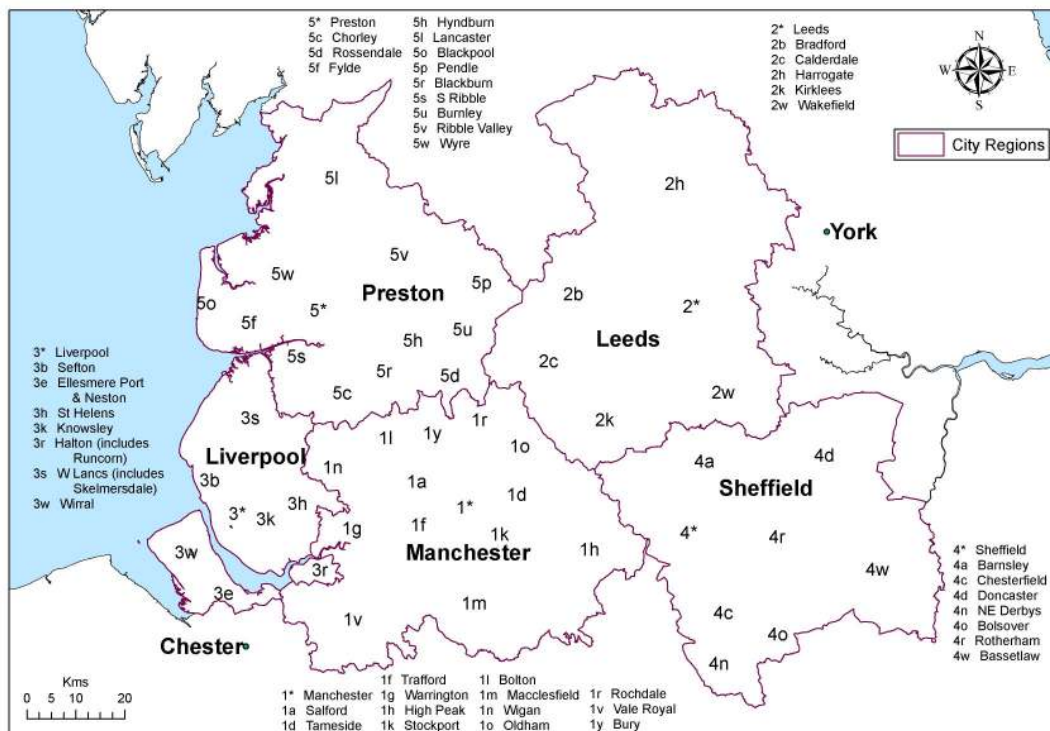
With reference to what was the world's first-ever major urban-industrial region, this paper investigates possible trends towards functional polycentricity between 1981 and 2001, a period in which it underwent rapid economic restructuring and population redistribution. The focus is on the five city regions which are currently seen as emerging in what were once the textile (and, to a lesser extent, steel) manufacturing areas of the former counties of Lancashire and the West Riding of Yorkshire, which we term Pennine England, now home to just over 10 million people. Owing its origins to water power from the Pennine rivers, this region now comprises many closely-spaced cities and towns whose distinct identities have been eroded through the loss of their local industrial specialisms and the long-term growth in mobility. As such, it inherits from the past a highly complex urban system within which there are major concerns about the future sustainability of all its individual parts, most notably the former industrial settlements located towards the peripheries of these city regions but also some of the city-region cores themselves.

The paper's aim is to test how far Pennine England may be evolving into a single polycentric mega-city region. In particular, have the largest centres strengthened their dominance over adjacent towns or has there been greater increase in centrifugal patterns or inter-peripheral flows which indicate more of a polycentric tendency? Commuting data from the 1981, 1991 and 2001 Population Censuses are used to test two hypotheses: firstly, that there is increasing polycentricity within each of the five city regions, i.e. they are decreasingly dominated by their main cities, with secondary centres emerging; and, secondly, that there is increasing linkage between the five city regions, with decreased dominance of the wider region by one centre, which historically has been Manchester. Following sections which document the development of the Pennine urban system and draw attention to the role of the Pennine region in conceptual development, the paper justifies the two hypotheses and reports the results of applying them to this region for the 1981-2001 period. The region has for long had a sluggish economy, so this case study complements the previous tests of emerging polycentricity, most of which have been undertaken for more dynamic regions.

Development of the Pennine urban system

Figure 1 shows the five city regions of the Pennine study area, of which Manchester is the principal urban centre in modern times. The central ‘spine’ of this region is the Pennine upland area which is over 500 metres in several places and forms the eastern boundary of the Manchester city region (and the border between Lancashire and Yorkshire). Despite its large land mass, the Pennine region includes no historic city. This partially reflects the territory here being bounded so that it lies between the two historic cities in this part of England, Chester and York. Yet the lack of cities genuinely reflects the Pennine region in pre-industrial times because English medieval cities are almost all coastal or located on navigable rivers, and generally in favourable agricultural areas. Much of the Pennine region is not readily fertile, especially the upland area – “waste” in the terms of Young (1773) – and so was too sparsely populated to support cities. Lower in the English medieval urban hierarchy was a comprehensive distribution of market towns. A list in Stow (1722) includes nearly 50 market towns in the Pennine study area.

Figure 1. *Pennine England: the five city regions and their districts*



Up to the start of the eighteenth century the region was very largely dependent on its limited agriculture: Gibbins (1890) emphasises how little manufacturing took place in the north of England in medieval times. The earliest industrialisation was on the western side of the Pennine region, most especially with the development of the Lancashire cotton industry. Charlesworth (c.1778, p. 419) referred to Lancashire as being “famous for its manufactures...and the treasures contained within the bowels of the mountainous districts”. The associated urban growth led him to then highlight the phenomenon that “Liverpoole [sic], no very ancient town, is neat and populous...[its] inhabitants drive an incredible trade with very large stocks to all the northern and southern parts of the world”. He also put great emphasis on Manchester being “a place of great trade” and noted that its lack of historic status meant that it could “be said to be the greatest village in England...though it is more populous than York or many other cities in England”. These remarks are notable because for many other counties only their county town merits any description in this survey of the geography of England: indeed the whole of the eastern part of the Pennine region receives no mention at all. One reason for this east-west contrast was the wetter climate of the west which was conducive to the cotton industry.

The hills and rainfall that had limited agriculture were valuable for early industry and its new technology of water powered machinery. The advent of steam power allowed factories to develop further using the local coal noted by Charlesworth (c. 1778). Development of the wool industry into the nineteenth century produced rapid growth in west Yorkshire where coal was also plentiful. Thus in a relatively short period the Pennine region was transformed due to unprecedented industrialisation. Its new urban form, the industrial town, was arguably a development that would not have occurred in a historic city where rapid urban growth would be hindered by town walls, while industrial innovations would be resisted by trade guilds. The unprecedented urbanisation underway as the Victorian era opened made Manchester “the shock city of the 1840s” (Briggs, 1968, p. 56).

The growth of railways led to the development of holiday resorts, and resorts like Blackpool and Harrogate figure prominently among larger current urban areas absent from the market towns listed by Stow (1722). Thus resorts were ‘new towns’ in the nineteenth century, whereas most towns with growth from basic or manufacturing

industry had been pre-industrial market towns (nb. this rapid growth of historically modest market towns is seen as a peculiarly English phenomenon by Dickinson 1961). For example, the steel and coal industry centres of Yorkshire (Sheffield, Rotherham, Barnsley, Doncaster) were all medieval market towns.

The unprecedented urbanisation of the Pennine region is summarisable as follows.

- Closely-spaced pre-industrial market towns interspersed among the Pennines were transformed into substantial urban areas heavily dependent on mining and/or specific manufacturing industries.
- Only a few major towns of the modern landscape were *not* pre-industrial market towns.
- Few towns had distinct rural hinterlands after industrialisation because they physically absorbed most of the nearby villages.
- The largest centres like Manchester absorbed open land between themselves and growing neighbouring towns like Stockport.

The processes described above combined to create by 1901 what Rodgers (1986) termed the “incipient conurbation” centred on Manchester. Indeed, well before this observation, Pennine England’s path-breaking urbanisation had led to it becoming the focus for studies which developed several of the key concepts that still underpin urban research. Recognition of the processes producing conurbations, and the concentration of key activities in the cities, was largely due to needing to understand the emerging urban system of this region a century ago.

First among these studies, Mackinder (1902, p. 335) saw that “a number of considerable towns, many of them ancient local centres transformed by new industrial activities, are rapidly growing...Owing to the concentration of affairs towards the heart of each of the great cities, rents have there risen, and it is no longer remunerative to manufacture in the immediate neighbourhood...South-eastern Lancashire is now a single economic unit, of which Manchester is the commercial centre within a vast ring of factory-groups.” Illustrating these processes, Mackinder (1902, Fig 131) identified the “towns within a radius of thirty-five miles of Manchester” and it is notable that this encompassed the four other cities whose city regions are analysed here (Figure 1).

The first use of the term “city region” is attributed to Geddes (1915) who compared London and its hinterland with the Lancashire part of the Pennine region and argued that the individual cities of Manchester and Liverpool “are fast becoming little more than historic expressions...we have here another vast province almost covered with house-groups, swiftly spreading into one, and already connected up at many points...another Greater London as it were, a city region” (pp. 12-13). In grouping together the areas around Liverpool and Manchester (as a single region he called “Lancaster”), Geddes was anticipating the process under examination here, the merging together into a single polycentric region of several previously distinct city regions (in the sense that the term ‘city region’ is used here viz: a functionally integrated region with a single dominant city).

The term conurbation, also coined by Geddes (1915), was based on a formal rather than functional approach to definition, but was almost as readily be applied to Pennine England, most notably by Fawcett (1922) in his pioneering measurement of Britain’s largest urbanised areas. The seven most populous continuously built-up urban regions which he identified included the two Lancashire cases of Liverpool and Manchester plus a West Riding of Yorkshire case that was dominated by Leeds. Revisiting the analysis later with data from the 1931 Census, Fawcett (1932, p. 105) noted that the Sheffield urban region was a marginal case for recognition as a major conurbation. The other city region within the Pennine region study area (“Preston” in Figure 1) extends across five smaller urban areas that Fawcett (1932) identified individually as significant towns that had outgrown their official boundaries. All these areas were encompassed by what Fawcett, in an echo of Mackinder (1902), stated was “the second great urban region of Britain, the area within a 50-mile radius from Manchester Town Hall” (Fawcett 1932, p. 109). The final point of relevance here was that the population of this Pennine region had hardly grown between 1921 and 1931 whereas the comparator London region grew markedly in that period.

In sum, during a thirty year period at the start of the twentieth century the exceptional urbanisation of the Pennine region was the focus of attention for a number of innovative researchers who developed key concepts to comprehend its complex form: conurbations are previously separate built-up areas that had merged; city regions are sets of settlements – of which one, the city, is increasingly dominant – which are

functionally interdependent. Five city regions are here grouped together as the Pennine region because of their similar development trajectories: their precocious urban growth, led by the very early industrialisation around the central point of Manchester, then sustained relative decline and/or dispersed growth since the 1920s. Given this background, it is clear that the Pennine region is a very fitting case for testing the evidence on the more recent notion of polycentricity which Kloosterman and Musterd (2001) conceive as an urban system that is rather densely populated, featuring several large cities of which none is totally dominant.

The topic of polycentric development in the Pennine region is also highly relevant in present-day policy terms. The region contains five of the city regions identified by ‘The Northern Way’, an initiative designed by the New Labour government as part of its Sustainable Cities Programme for stimulating agglomeration economies across the wider region (Northern Way, 2004, 2009). Building a more coherent polycentric entity was seen as a positive contribution to this development, based on the idea that increasing the connectivity between urban centres in the North of England and strengthening the economic linkages between Leeds and Manchester could generate enough extra mass to compete effectively against the national capital region (Harding and Rees, 2010; SERC, 2009). While this initiative has been swept away by the current Coalition government along with abolition of the Regional Development Agencies, these issues still remain, not least in discussions over the next steps in the national planning of high-speed rail transport and whether improvements in transport within the region would be more beneficial to its future long-term economic growth than the proposed HS2 line from London with its separate links to Leeds and Manchester (see, for instance, Overman, 2012).

Testing for Growing Polycentricity

To date, there are relative few empirical studies aiming to test the existence of polycentric regions and a single preferred approach has yet to emerge. Most simply, their tests can be seen to focus on either pattern or process. The former emphasises the geographical make-up of the region, whether in socio-demographic or economic or

other terms. For example, a polycentric region might see residential sorting such that its settlements become distinct in terms of household characteristics like life stage, income and ethnicity (see Champion, 2001a; Musterd and Van Zelm, 2001). Similarly, the local specialisation in economic activity of the individual parts of the region can lead to higher-level services or consumer-oriented production being provided in different places for the whole region: example studies of sectoral specialisation include Bailey and Turok (2001) on central Scotland, Vanhaverbeke (1998) on the Flemish Diamond, Franz and Hornych (2010) on the Saxony Triangle, Kloosterman and Lambregts (2001) and Meijers (2005) on the Randstad and Blotevogel (1998) on Rhine-Ruhr.

The more process-oriented studies could, at least in principle, examine indicators ranging from flows of people and movements of goods to business networks (Limtanakool *et al.*, 2010). In practice, De Goei *et al.* (2010) observe relatively few examples of empirical studies that have quantitatively assessed polycentricity and, of these, most focus on people flows, and most usually on commuting. Commuting patterns in modern countries have increased in average length and also become more diffuse in their spatial pattern (Aguilera, 2005; Axhausen, 2010) which can be seen as a manifestation of, or partly causing, increasing polycentricity (Clark and Kuijpers-Linde, 1994; Green, 2008; Lang and Knox, 2009). Data availability has also played a crucial role because “commuting data is still the most elaborate, reliable and relevant interaction data available” (Burger *et al.* (2011: 161). Kloosterman and Lambregts (2001) had the same view, in the absence of similarly detailed reliable data on other travel by the people of a region.

This paper follows the practice of using commuting data for its tests of polycentricity, but there are two principal elements of originality. Firstly, most previous studies have analysed commuting data at one time point, such as the major POLYNET study that calculated polycentricity indices for “c. 2000” (Hall *et al.*, 2006, Table 2.2). Notable exceptions are the pioneering work by Clark and Kuijpers-Linde (1994) on southern California and the Randstad, and the recent studies by De Goei *et al.* (2010) and Burger *et al.* (2011) with the British Censuses of 1981 and 2001. This paper echoes the latter in its data source and reference period, but here the same 20-year period is broken down into the two separate intercensal decades so that any changing urban

system dynamics can be observed. Secondly, like De Goei *et al.* (2010), we model the patterns at two geographical scales, i.e. both within and between city regions, but rather than analyse these separately, here a single model is used to test both for the changing dominance of the central city within its own city region and for the changing strength of the barrier effect posed by the city region boundaries.

The mention above of declining distance deterrence means that increasing commuter flows within and between Pennine city regions will not in itself demonstrate increasing polycentricity. To allow for this, our modelling approach takes declining distance deterrence into account so that specific indicators can identify any trends towards greater polycentricity within the changing patterns of commuting. For this purpose, we use a standard gravity model which includes distance between places alongside dummy variables designed to capture the two processes that we are testing for, namely:

- 1 *within* city regions, whether the cities have lost dominance as attractors of commuters
- 2 *between* city regions, whether there has been an increase in commuting across the boundaries between the five city regions.

The basic form of the gravity model is: $T_{ij}=a*O_i*D_j*d_{ij}$, where T_{ij} is the predicted number of trips between zones i and j , O_i is the total number of trips originating in zone i , D_j is the total number of trips terminating in zone j , and d_{ij} is a measure of distance between zones i and j . To this we add the two dummy variables: dum_1 indicating flows to the city of a city region from a different zone in the same city region, and dum_2 indicating flows that cross a city region boundary. To estimate the parameters on each of the independent variables, the model is logged to produce: $\log(T_{ij})=a*\log(O_i)+b*\log(D_j)+c*\log(d_{ij})+e_1*\log(dum_1)+e_2*\log(dum_2)+\log(f)$, where the last term is the constant or intercept.

As already mentioned, the data we use are derived from the 1981, 1991 and 2001 Censuses, specifically their Special Workplace Statistics. These give us counts of flows between the 49 local authority districts of Pennine England shown in Figure 1, including intra-district flows but excluding exchanges with the rest of the country, giving a matrix of 2401 cells. We have had to make some adjustments to the

published data. In a very small number of cases, the district boundaries changed between 1991 and 2001, so the two earlier datasets were ‘best-fitted’ to 2001 zones by the Centre for Interaction Data Estimation & Research (see acknowledgements). Secondly, whereas the earlier datasets were derived from a 10% sample of Census forms, the 2001 dataset gives a 100% coverage, so the latter was converted to ‘pseudo 10%’ by dividing by 10 and then rounding, and then all three were multiplied by 10 to give an estimate of the total number of commuters. Thirdly, so that the analysis of logged flows could cover the whole system at each date, including zero-count cells, an arbitrary figure of 1 was added to all cell counts. Some inconsistencies are not resolvable and their level of influence is unclear (see the concluding discussion).

Finally, as regards the distance variable, the distances between district pairs were calculated as the mean of the distances from all wards in zone A to all wards in zone B (as in Fotheringham *et al.*, 2000). This procedure yields more accurate measures than using zone centroids would, and also provides plausible intra-zonal distances (although possibly over-estimating these for some extensive rural areas).

In sum, our tests for growing polycentricity in Pennine England over 1981-2001 use adjusted versions of the inter-district commuting matrices of the three relevant censuses. Each matrix is analysed with a basic gravity model to which are subsequently added terms representing the two measures of polycentricity designed to test trends at the two scales of within and between city regions. The devised distance variable is more sophisticated than one based on distance between district centroids, but does not take account of actual network distances, nor of travel time or cost by specific modes.

Results from the modelling

Our presentation of the findings from the modelling proceeds in two steps. First, a look is taken at the results of applying the simplest form of gravity model that uses just the origin and destination mass terms and the distance variable. Then these are compared with the results of adding to the basic model the two polycentricity-test

dummy variables. The two sets of results can be found in Table 1's panels A and B respectively.

Table 1. *Modelling results (N=2401)*

A: Simple gravity model

| Year | 1981 | 1991 | 2001 |
|-------------------------|--------|--------|--------|
| adjusted R ² | 0.780 | 0.795 | 0.857 |
| distance deterrence | -3.538 | -3.476 | -3.304 |
| origin zone size | 0.499 | 0.583 | 0.674 |
| destination zone size | 0.865 | 0.939 | 0.961 |

B: Expanded gravity model

| Year | 1981 | 1991 | 2001 |
|--------------------------|--------|--------|--------|
| adjusted R ² | 0.797 | 0.807 | 0.863 |
| distance deterrence | -3.051 | -3.080 | -3.019 |
| origin zone size | 0.549 | 0.624 | 0.702 |
| destination zone size | 0.875 | 0.948 | 0.971 |
| to city (of city region) | 0.325 | 0.251 | 0.152 |
| between city region | -0.465 | -0.379 | -0.275 |

The results of the basic gravity model reported in Table 1A comprise four measures for each time point: the level of explanation (adjusted R²), the distance deterrence parameter, and the parameters for the two mass terms. The first of these indicates a relatively high fit of the model's 2401 estimated flows to the observed flows, as is usual in this form of interaction modelling. What it also shows is the level of explanation rising progressively over time, with a particularly large increase in the second period. By 2001 the model 'explains' nearly 86% of the variance in flows across Pennine England, up from 78% in 1981 and 80% in 1991. It seems unlikely that this level of change could be a statistical artefact arising from change in the basis of the data. Instead, the most likely interpretation is that the whole of Pennine England is becoming more interconnected by commuting flows and that, as part of this process, there has been a reduced influence of distinctive local factors which made people commute in ways contrary to the assumptions behind the basic gravity model.

The results for the three sets of parameters in this model (Table 1A) certainly indicate growth in between-district commuting. Distance deterrence falls progressively between the three dates, and especially in the second period. Meanwhile, the substantial increase in the parameter for the origin mass term suggests that over time the districts are progressively putting more workers into the full inter-district matrix pro rata of their workforce. Similarly, the rise in the destination area parameter suggests that a given level of ‘jobs’ (measured as people in work counted at their workplace) was generating more inward commuters in 1991 than in 1981 and in 2001 than in 1991. This interpretation is consistent with the fact (derived from a separate analysis of the datasets) that the proportion of all commuting in Pennine England that involved crossing a district boundary has been steadily rising, up from 23.9% in 1981 to 27.2% in 1991 and to 30.9% in 2001, meaning an overall decrease of 7 percentage points in the proportion of people working in the district where they live.

Turning to the results of the full model that includes the two dummy variables (Table 1B), these reveal support for both of the ‘growing polycentricity’ tests. The ‘To City’ dummy’s parameter is positive at all three times, indicating that the five cities attract more commuters from other districts in their own city regions than would be expected from the overall commuting patterns across Pennine England, but the parameter shrinks substantially in size over time, down from 0.33 in 1981 to 0.15 in 2001. The attractive power of these city-region cores has clearly been waning over the study period. This interpretation is supported by separate analyses of these datasets showing that the proportion of all Pennine England commuting that was between districts in the same city region *but* neither started nor ended in a central city district increased by nearly 4 percentage points between 1981 and 2001.

In relation to the second hypothesis, the damping effect imposed on commuting flows by the boundaries between the five city regions has also fallen markedly, down from -0.47 in 1981 to -0.28 in 2001. Evidently, the city-region boundaries do continue to push interaction levels below the level that would be expected from the behaviour across the whole system based on the size of places and the distance between them, but the scale of their deterrence effect has been reducing over time. This is also reflected in the proportion of all Pennine England commuting flows that crossed a

city-region boundary rising by a full percentage point in 1981-1991 and then by slightly more than this in 1991-2001.

The inclusion of these two dummy variables does not generally alter the parameters of the other variables much. Just as in the basic gravity model results in Table 1A, the levels of explanation (R^2) again rise over time in Table 1B, while similarly the parameters on the two mass terms also continue to increase over time. But there is one change in pattern from the basic gravity model. The parameter for the distance variable no longer falls progressively over time, but instead rises between 1981 and 1991 (from -3.05 to -3.08) before falling to -3.02 in 2001. Even the fall in 1991-2001 was much smaller than the fall in the basic model at this time (of -3.48 to -3.30), while the overall reduction of just 0.03 points between 1981 and 2001 is hugely smaller than the 0.24 points reduction in the basic model. This suggests that the overall fall in deterrence in the basic model is almost entirely explained by the changes represented by the two polycentricity tests.

In sum, the first polycentricity hypothesis, tested with the dummy variable that identifies flows from non-city zones to the city of their city region, yields results suggestive of a less monocentric pattern emerging and is consistent with polycentric development at this city-region scale, though it may also result from 'sprawl' (as identified in the region by Nuisl *et al.*, 2007). The second polycentricity hypothesis, concerning integration of the five city regions and tested with the dummy variable that identifies inter-city region flows, gives a declining value that indicates some merging of city regions. As a further conclusion, these two sets of changes relating to increasing polycentricity seems to account for almost all of the reduction in the overall distance deterrent effect noted in the basic gravity model results.

Conclusions

This paper has performed two tests for growing functional polycentricity on a region that has inherited a highly complex pattern of physical polycentricity, due to its role as the world's first major urban-industrial region, but that has also become increasingly

organised as city regions based on five main centres. Both of the tests, one devised to measure developments at the intra-city-region scale and the other at the inter-city-region scale, have indicated a tendency of increasing functional polycentricity between 1981 and 2001, with a fairly steady progression across the two decades. Over this period there has been a reduction in the five cities' attraction of commuters living in the other parts of their city regions. Secondly, the boundaries between the city regions seem to have become more permeable over time. Nevertheless, the fact that, after allowing for these two factors, distance deterrence appears to remain almost constant suggests that in all other respects there has been no significant change in the ability, need or willingness to commute longer distances. All that seems to have happened, as reflected in the increase in the models' levels of explanation over time, is that local differences in people's responses to commuting's drivers and deterrents have reduced over time.

As a rider, this research is still at a fairly exploratory stage, though we are confident about one aspect. As the results show a high degree of regularity in trend over time, it would seem that they are not significantly affected by data inconsistencies between the three censuses related to changes in the wording of the workplace question and the coding procedures, in the methods used for disclosure control and tackling non-response, and in the usual address of students (term-time in 2001 and vacation previously). There are, however, several ways in which this work could be taken forward. One is to experiment with alternative forms of the gravity model, including using singly or doubly constrained versions and substituting velocity for flow as the dependent variable. Another is to use selected flow data, including for specific occupations, from the commuting matrices or to seek other evidence to check on our interpretation of the results and possibly help devise additional indicators for testing for polycentricity. Thirdly, we could try to see whether there is anything distinctive about Pennine England by applying our model to another case study area, possibly the more dynamic region of the Greater South East of England as already studied by De Goei *et al.* (2010) using a somewhat similar approach. Fourthly, given that the analysis so far has been restricted to the standard geography of local government districts, it might be worth exploring data for alternative, especially finer-grained, geographies that more closely represent the settlement system and the changing distribution of jobs within it. Lastly, and partly related to this, commuting data from

the 2011 Census will in due course provide the opportunity to add a third decade of change and looks likely to adopt a lower tier of geography with more consistently sized units.

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