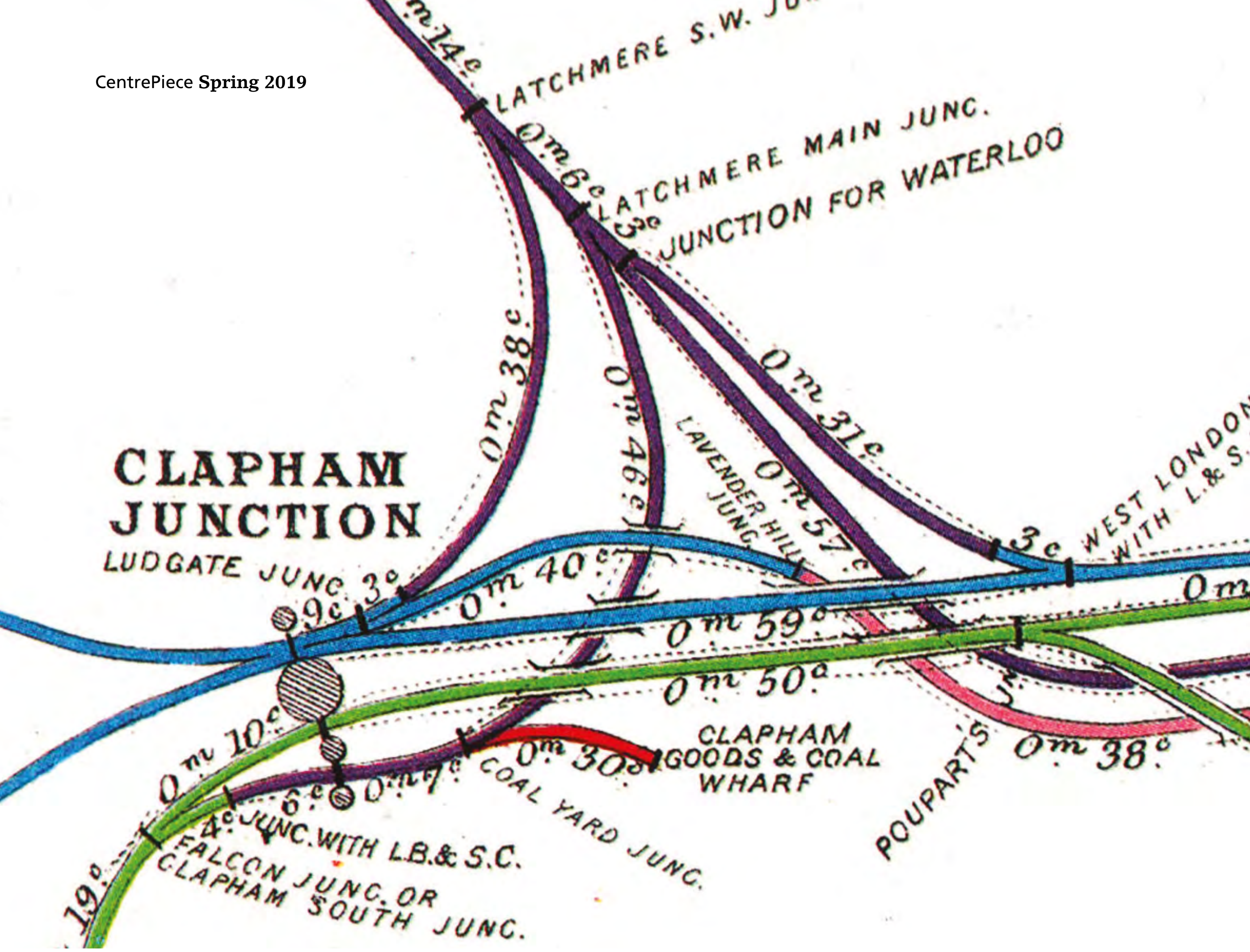
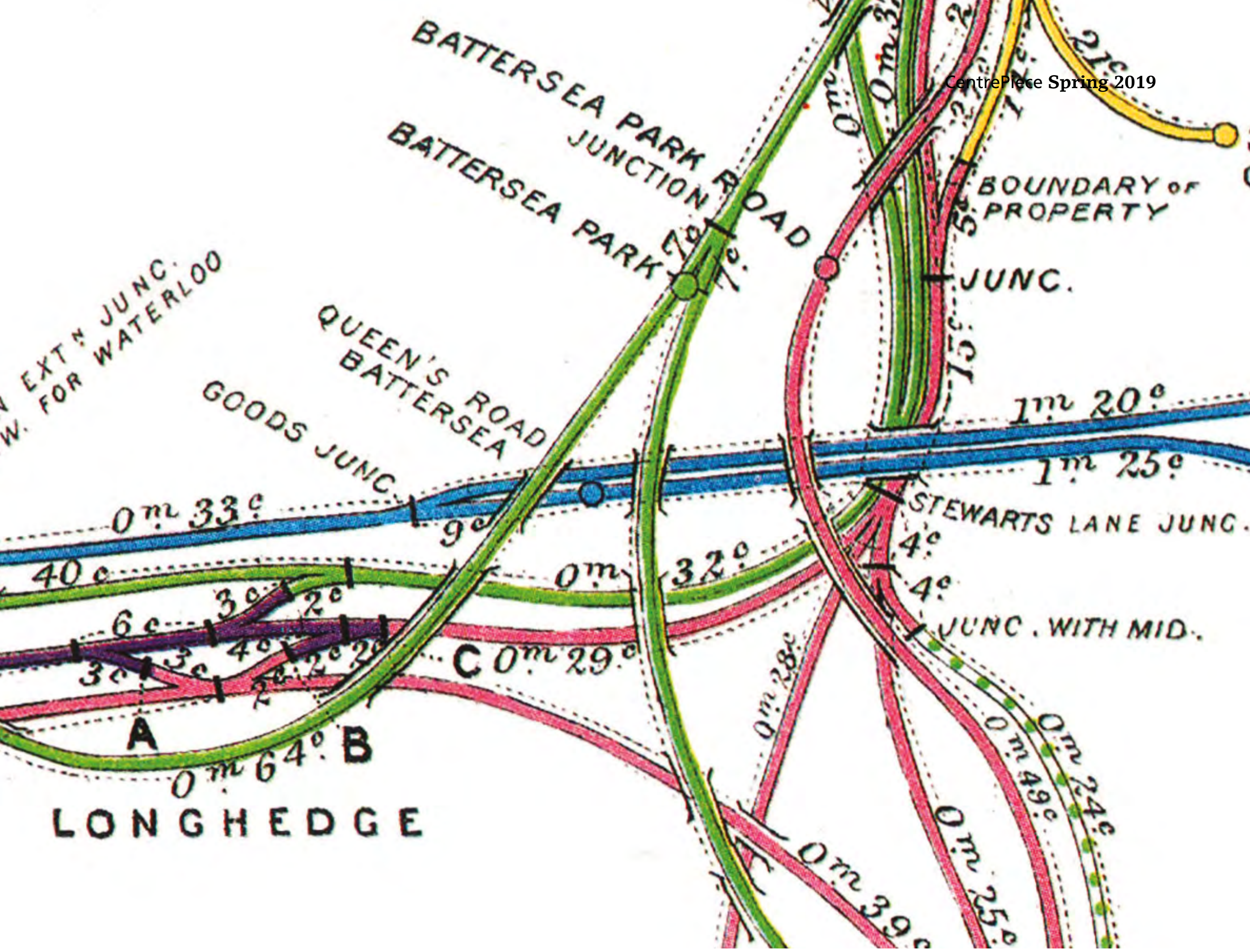


Over the last two centuries, transport innovations have drastically changed urban landscapes. **Stephan Heblich**, **Stephen Redding** and **Daniel Sturm** examine how the introduction of steam railways shaped the emerging metropolitan area of London.

The making of the modern metropolis: evidence from London



Modern metropolitan areas include vast concentrations of economic activity, with Greater London and New York City today accounting for around 8.4 and 8.5 million people, respectively.

These intense concentrations of population involve the transport of millions of people each day between their home and work, as surveyed in Redding and Turner (2015). Today, the London Underground alone handles around 3.5 million passenger journeys per day, and its trains travel around 76 million kilometres each year (about 200 times the distance between the earth and the moon).

Yet relatively little is known about the role of these commuting flows in sustaining dense concentrations of economic activity. On the one hand, they impose substantial real resource costs, both in terms of time spent commuting and the construction of large networks of complex transport infrastructure. On the other hand, they are also central to the creation of predominantly commercial and residential areas, with their distinctive characteristics for production and consumption.

How the separation of workplace and residence led to agglomeration

Our research uses the mid-nineteenth century transport revolution from the invention of steam railways, a newly created, spatially disaggregated dataset for Greater London between 1801 and 1921, and a quantitative urban model to provide new evidence on the contribution of the separation of workplace and residence to agglomeration.

The key idea behind our approach is that the slow travel times achievable solely by human or horse power implied that when these were the main modes of transport, most people lived close to where they worked.

In contrast, the invention of steam railways dramatically reduced the time taken to travel a given distance, increasing average travel speeds from around 6 mph (miles per hour) for horse-drawn vehicles and 3 mph for walking to around 21 mph on the train. This permitted the first large-scale separation of workplace and residence, which in turn enabled locations to specialise either as places to work or places to live.

We find substantial effects of steam passenger railways on city size and structure. Our model is able to account both qualitatively and quantitatively for the observed changes in the organisation of economic activity within Greater London.

London during the nineteenth century is arguably the poster child for the large metropolitan areas observed around the world today. In 1801, London's built-up area housed around 1 million people and spanned only five miles east to west. In contrast, by 1901, Greater London contained over 6.5 million people, measured more than 17 miles across, and was on a dramatically larger scale than any previous urban area.

By the beginning of the twentieth century, London was the largest city in the world by some margin (with New York City and Greater Paris having populations of 3.4 and 4 million, respectively), and London's population exceeded that of several European countries.

Furthermore, London developed through a largely haphazard and organic process during this period, which suggests that both the size and structure of the city responded to decentralised market forces. Therefore, nineteenth century London provides a natural testing ground for assessing the empirical relevance of models of city size and structure.

The impact of steam railways on the organisation of economic activity

We begin by providing several pieces of evidence on the impact of steam railways on the organisation of economic activity within Greater London. We first establish changes in parish population growth rates that coincide closely with the arrival of the railway. We next show that these changes in population growth are heterogeneous across parishes.

Figure 1 shows average population growth in the 30 years after the arrival of a railway station minus average population growth in the 30 years before its arrival. As is apparent from the figure, we find that more central parishes (as measured by distance to the Guildhall in the City of London) experience a decline in population growth relative to more suburban parishes, consistent with the railway redistributing residential population within Greater London.

To interpret this evidence, we develop a new procedure for an entire class of urban models characterised by a 'gravity equation' for commuting. Although we only observe bilateral commuting flows between the 99 boroughs within the boundaries of Greater London at the end of our sample period in 1921, we show how this framework can be used to estimate the impact of the construction of the railway network.

In a first step, we use our bilateral commuting data for 1921 to estimate the parameters that determine commuting costs. In a second step, we combine these parameter estimates with historical data on population, land values and the evolution of the over- and underground railway network going back to the early nineteenth century.

Using a combined commuter and land market clearing condition in the model, we solve for the implied unobserved historical values for employment by workplace and commuting patterns. Although we estimate the model's commuting parameters using 1921 information alone, we find that its predictions provide a good approximation to the available historical data.

As Figure 2 shows, we find that the model captures the sharp divergence between the night-time and day-time population in the City of London from the mid-nineteenth century onwards. We also find that the model replicates the property of early commuting data that most people lived close to where they worked at the dawn of the railway age.

Our methodology holds in an entire class of urban models, because it uses only the assumptions of gravity in commuting and land market clearing, together with the requirements that payments for residential floor space are proportional to residential income and payments for commercial floor space are proportional to workplace income.

Much of the aggregate growth of Greater London can be explained by the new transport technology of the railway

Figure 1:

Changes in parish population growth rates between the 30-year period after the arrival of a railway station and the 30-year period before its arrival

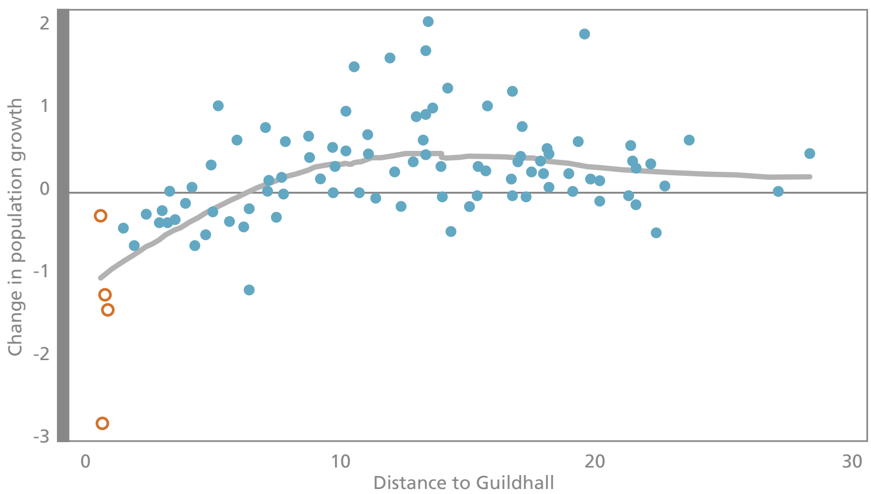
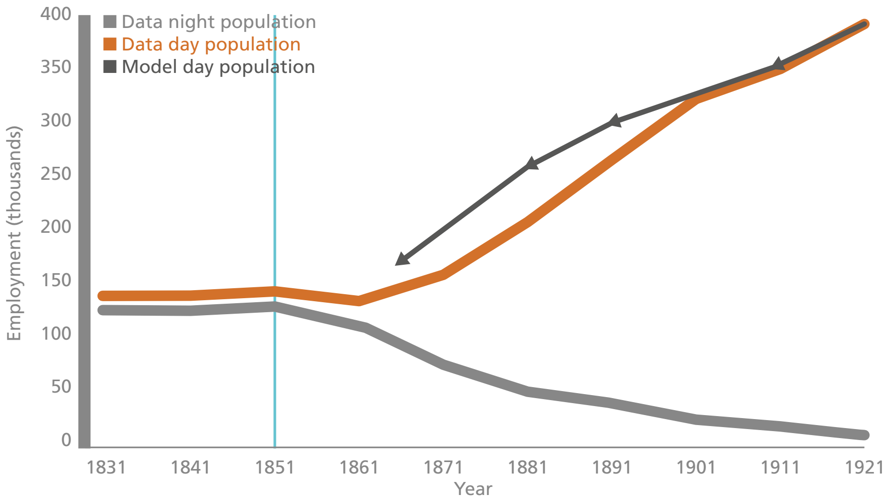


Figure 2:
Day-time and night-time population in the City of London in the data and our theoretical model



An implication of this property is that our results hold under a range of assumptions about other model components, such as the costs of trading goods, the determinants of productivity and amenities including the strength of agglomeration forces, the supply of floor space and changes in economic conditions in the rest of the country.

Given the data for the initial equilibrium in 1921, we show that the observed changes in population and land values are sufficient statistics in the model for determining historical workplace employment and commuting patterns, and control for other potential determinants of the spatial distribution of economic activity.

While our baseline quantitative analysis controls for these other forces, another key question of interest is the counterfactual of what would have been the effect of the new commuting technology in the absence of any other changes.

To address this question, we make additional assumptions about these other model components, and pick one quantitative model within our class of urban models in order to solve for a counterfactual equilibrium. In particular, we choose an extension of the canonical urban model of goods trade and commuting following Ahlfeldt et al (2015), which is particularly tractable, and enables us to explore alternative assumptions about structural parameters in a transparent and flexible way.

Holding the supply of floor space, productivity and amenities constant, we find that removing the entire railway network reduces the total population and rateable value of Greater London by 30% and 22% respectively, and decreases commuting into the City of London from more than 370,000 people in 1921 to less than 60,000.

By comparison, removing only the underground railway network diminishes the total population and rateable values for Greater London by 8% and 6% respectively, and brings down commuting into the City of London to just under 300,000 workers.

In both cases, the changes in the net present value of land and buildings substantially exceeds historical estimates of the construction cost of the railway network. Allowing the supply of floor space to respond to changes in its price or introducing agglomeration economies magnifies these effects.

Calibrating the responsiveness of the supply of floor space using the observed data, and assuming values for the strength of agglomeration forces in line with existing empirical estimates, we find that much of the aggregate growth of Greater London can be explained by the new transport technology of the railway.

Concluding remarks

Taken together, we find that a class of quantitative urban models is remarkably successful in explaining the large-scale changes in the organisation of economic activity observed in nineteenth century London.

Our findings highlight the role of modern transport technologies in sustaining dense concentrations of economic activity. We show that these transport networks explain the sharp separation of workplace and residence observed today and were responsible for a substantial proportion of London's aggregate population growth and increases in the value of land and buildings over the period 1801 to 1921. These increases in the value of land and building are substantially greater than historical estimates of the construction costs of these networks.

This article summarises 'The Making of the Modern Metropolis: Evidence from London' by Stephan Heblich, Stephen Redding and Daniel Sturm, CEP Discussion Paper No. 1573 (http://cep.lse.ac.uk/pubs/download/dp1573.pdf).

Stephan Heblich of the University of Bristol is a research associate in CEP's urban programme. **Stephen Redding** of Princeton University and **Daniel Sturm**, LSE professor of economics, are research associates in CEP's trade programme.

Further reading

Gabriel Ahlfeldt, Stephen Redding, Daniel Sturm and Nikolaus Wolf (2015) 'The Economics of Density: Evidence from the Berlin Wall', *Econometrica* 83(6): 2127-89 (earlier version available as CEP Discussion Paper No. 1154: http://cep.lse.ac.uk/pubs/download/dp1154.pdf).

Stephen Redding and Matthew Turner (2015) 'Transportation Costs and the Spatial Organization of Economic Activity', in *Handbook of Urban and Regional Economics, Volume 5* edited by Gilles Duranton, Vernon Henderson and William Strange, Elsevier.

Without the railway network, Greater London's population would have been at least 30% lower in 1921