Can transport infrastructure change regions' economic fortunes: some evidence from Europe and China

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Abstract

Claims and counterclaims about the likely impact of new transport infrastructure on a region's economic performance have existed for centuries going back to the early days of canals and railways. High-speed rail (hereafter HSR) as a new type of infrastructure has just over 50 years of existence. The persistent debate is questioning the power of HSR in reducing economic disparities between cities and effecting economic transformation. The paper goes beyond macro-modelling, looking to more disaggregated approaches of the structural changes. Two regions, one in Europe and one in China are compared to gain insights for future research and practice.

Keywords

High-speed Rail, Transport and Infrastructure, Wider Economic Impacts, Economic Transformation, Regional Development

JEL classifications

R11, L92, R42, R58

Introduction

How transport affects economic performance has been a recurring theme in discussions on transport appraisal. Traditional views were that a well-constituted cost-benefit analysis would include all such effects as part of the user benefits; to include any additional effects would involve double-counting. However, this depends on assuming that there is perfect competition in the rest of the economy. Where this does not occur there is scope for transport improvements to give rise to increased productivity and agglomeration effects that are cumulative. In this context transport infrastructure can have the potential to transform economies. The debate on these wider economic impacts of major infrastructure projects has developed considerably. This has been particularly the case in the UK over the last 10 years since the appraisal of Crossrail, which provided hard evidence of the scale of these potential impacts. The concern remains, however, that any such local effects may be essentially redistributional rather than having a net impact on economic performance overall. This is significant because it can provide the basis for an argument in support of the use of public funds in a project to ensure the capture of these wider impacts.

In this paper we look at the specific case of high-speed rail (HSR) that has the potential to create step-changes in accessibility. Can the development of such infrastructure have a transformational effect on economies? We first examine the theoretical arguments for the existence of wider economic impacts. We then look at possible empirical methods to evaluate these before assembling some evidence from existing HSR projects in Europe and China to determine whether there is a case for their existence, and whether there are differences in these effects in the different geographical situations. In contrast to studies that have estimated aggregate impacts on national or regional economies (see Ansar et al. 2016 for a recent attempt to do this for China), we focus here on the structural changes in city regions and have chosen two that experienced the arrival of high-speed rail at around the same time. Although these two, the Yangtze River Delta in China and Kent in the UK, are very different in scale, they both represent regions close to a major metropolitan area, Shanghai and London respectively. Finally, we suggest some ways forward in moving to a more robust and transparent way of assessing such impacts.

The wider economic impacts debate

Transport infrastructure has, for a long time, been the source of speculation concerning its impact on the economy; many studies have been published in this journal over that time. More than 50 years ago Fogel (1964) raised the question of the role of railways in the economic development of the United States and the question of the 'social dividend' from historical transport developments such as canals and railways has continued to fascinate economic historians (Leunig, 2010). In the aggregate it is possible to identify a high degree of correlation between transport investment and economic performance; higher levels of investment are associated with higher levels of productivity and growth. Following the work of Aschauer (1989) there was quite an industry in demonstrating this at both national and regional level. Aschauer tried to demonstrate that publically provided infrastructure could raise the level of private productivity and thus counter any fear that it crowded out private investments. But there is a much longer history going back to the works of von Thünen (1826), Christaller (1933), and Lösch (1940) that focussed on the role of accessibility in determining the importance of central places.

Using the gravity model showing how the interactions between two locations depend on the economic mass of those places and the friction of the intervening distance between them, geographers showed how this economic potential of locations could be affected by improvements in infrastructure that reduced the access times between them (Clark et al. 1969;

Keeble et al, 1982a). Keeble et al (1982b) suggested that, assuming that the Channel Tunnel reduced journey times to those of the equivalent land distance, South East England would show an increase in potential of 10.05% and a 4.98% increase relative to the maximum potential in the European Community (given that the potential of all regions would increase if average accessibility increased).

The problem with these aggregate measures using the volume of investment or distance-based accessibility is that they do not distinguish differences in industrial structure or the potential of regions to take advantage of new opportunities. Often analyses of the impact of new infrastructure are taken from the perspective of the region promoting the scheme; the analysis shows how the improved accessibility will open up new markets for the region's industries, but ignores the fact that all such transport improvements work in both directions and open up the region's industries to more competition. It is very easy to jump to the conclusion from this that those regions that are already more advanced are more likely to suck economic activity out of the relatively poorer region. This is a revival of the problem identified by Hotelling (1929) that small cities would be better campaigning for more barriers to access than better access if they wished to avoid their markets being swamped by goods from larger cities.

Vickerman (1987) suggested that the Channel Tunnel would not have the impact suggested by Keeble et al (1982b), at least on the regions lying between the major metropolitan areas. This idea that accessibility is not continuous is particularly relevant in the case of high-speed rail as in order to benefit from the increase in speed it is necessary to restrict the number of stops on the network. Vickerman et al (1999) demonstrated how these discontinuities would change the accessibility map of Europe with the adoption of the high-speed rail lines defined in the Trans-European Transport Networks. Major centres would continue to benefit, but many intermediate areas would not, whilst more peripheral centres would also not gain a major redistribution of enhanced relative accessibility. But accessibility, however measured, cannot be interpreted as economic benefit; to understand this requires an understanding of how firms and industries (and indeed individuals) use transport and, in particular how they use transport in imperfectly competitive markets. This leads us from the simple consideration of direct user benefits to that of wider impacts on the economy as a whole.

The more recent literature stems from the pioneering work of Paul Krugman (1991). This has been developed more formally by Fujita et al (1999) and others, and a useful application to appraisal in the transport case is given by Venables (2007). The implications of this work have recently been summarised by Venables et al (2014) for the Department for Transport in the UK. The essence of this so-called 'new economic geography' approach is that markets using transport are imperfectly competitive such that their response to falling transport costs is not necessarily an equivalent reduction in prices (see also Dodgson, 1973, 1974; Jara-Diaz, 1986). This implies that firms in larger cities will usually be more productive than firms in smaller cities due to agglomeration effects. Whereas conventional theory would argue that resources would then move towards the larger city until the cost differential was equalised, the new theory shows that a virtuous cycle can occur in which productivity continues to increase and the real wage to rise, confirming and reinforcing the advantage of the larger city over the smaller one. In this way transport improvements lead to divergence. But the new insight is that in some circumstances, depending on the initial level of transport costs between the two cities and the extent of the change, transport costs become less relevant for location choice and the smaller city can overcome the larger city's initial advantage. The key insight is that a given change in transport costs leads to an indeterminate change in the spatial distribution of the impact. Thus we cannot say a priori that a new transport infrastructure will be centralising or decentralising. Whilst this can be shown theoretically and numerically, empirical testing is more difficult, but using the framework of Venables (2007), Graham

(2007) related productivity change using firm level data to changes in the economic mass (effective employment density) of a location.

Graham developed the analysis initially on data for London to estimate the wider economic effects from the construction of a new urban railway, Crossrail, and the methodology has now been incorporated into the official guidance for transport analysis in the UK. What the work showed is that the elasticities of productivity with respect to a change in effective density were larger than most previous aggregate analyses of productivity and city size had suggested (see Glaeser and Gottlieb, 2009), and that this was particularly true for employment in sectors such as business and financial services. Such sectors are more likely to use, and benefit from, high-speed rail, and hence have the potential to change a region's economic structure, whereas highway improvements are likely to have a more neutral effect on structure as they increase accessibility and reduce transport costs more equally across all sectors.

Although clear evidence of wider economic benefits from transport investments exists for urban projects, these operate through impacts on clearly defined labour markets. Graham et al (2010) showed that these effects are very localised. Graham and Melo (2011) applied the same methodology to the case of the proposed HS2 high-speed rail line in the UK and suggested that such agglomeration effects would be relatively small. Those seeking to identify transformational effects of major infrastructures have developed models of business and labour connectivity between cities for HS2 (KPMG, 2013), between countries for airport expansion (PwC, 2103a) or more detailed computable general equilibrium models (PwC, 2013b). These suggest much more significant overall impacts on GDP from such projects and, although these identify winners and losers from such developments, the net gain is significantly positive. Not surprisingly these estimates have been subject to a degree of criticism, as they appear to suggest impacts on the economy much larger than anything previously estimated (Overman, 2013).

On the negative side, Ansar et al (2016) suggest that the assumption in the models discussed above, that lower transport costs translate into higher levels of productivity, which is beneficial to the economy, ignore the impact of typical underperformance relative to ex ante forecasts. This, they suggest, leads to macroeconomic risks because of the financial costs from the ways that such projects are financed through debt or taxation. This is a return to the crowding out hypothesis originally challenged by Aschauer (1989). We find this attempt to use project by project data to assess overall macroeconomic performance less helpful in understanding the impact of new transport infrastructure than an approach that focuses on the real economic impact on the local economies affected.

Estimating wider impacts

The problem with the theoretical model from the 'new economic geography' is that it does not have an analytical solution. Numerical simulations can show the range of possible outcomes, but this is less satisfactory as a decision making model to build into an appraisal framework or to estimate impacts ex post. Venables (2007) provided the link between the theoretical model and its potential use in an extended cost-benefit analysis framework. This was used in an empirical study by Graham (2007) and is the approach now adopted by the UK Department for Transport (2014) in its appraisal methodology WebTAG.

This model works well for large urban areas and was instrumental in the decision to proceed with the Crossrail project in London (Department for Transport, 2005) identifying wider impacts equal to more than 30% of the direct user benefits. These depend on relatively high elasticities associated with key employment sectors in the London metropolitan region such as financial and business services, when compared to the agglomeration elasticities traditionally found in urban size models that are heavily dominated by industrial sectors.

The model presents greater problems in dealing with larger scale inter-urban and inter-regional projects. Graham et al (2010) have shown that the distance decay applicable to the effective density calculations is quite steep suggesting that benefits are confined to quite small areas around access points such as rail stations. Graham and Melo (2011) found relatively minor additional impacts when applying essentially the same model structure to the proposed HS2 HSR link between London, Birmingham and the North.

Venables (2013) has suggested that the clustering that lies at the heart of the agglomeration story may in fact apply, not at the sectoral level, but rather at the level of skills and occupations. Thus in an inter-urban context it is activities that move and cluster, within sectors and even within firms, as the traditional Marshallian externalities operate more effectively at this level.

However, this attempt to extend the cost-benefit analysis framework to encompass wider impacts may not be the most appropriate way forward to understanding the overall impact on regional development from a major HSR project. Laird et al (2014) have attempted to map out the requirements of an extended CBA approach and contrast this with an alternative view that tries to go straight to the impact on output or gross value added (GVA). Models that try to do this have been around for many years in the form of land-use transport interaction (LUTI) models (Wegener, 2011). These have been supplemented in recent years by spatial computable equilibrium (SCGE) models (Bröcker and Mercenier, 2011).

The problem with these models is their dependence on imported data for calibration and the assumption of market clearing equilibrium. What is needed is an approach that allows for disaggregated behavioural responses to changing accessibility. One controversial approach is that developed by KPMG (2013) that attempts to estimate both labour market and business responses to changing accessibility to produce regional estimates of employment and output change. This has suggested that the potential impact of the HS2 network in the UK between London, Birmingham, Manchester and Leeds could be significantly greater than that suggested by conventional methods. The controversy has arisen over the assumptions made about modal elasticities from changing accessibility and the fact that very high, much higher than obtained from alternative methods, figures have been obtained for overall economic impact (House of Commons, 2013). In work related to the economic impacts of new airport runways in the UK, PwC (2013a) also explored connectivity between countries and subsequently developed a computable general equilibrium model for this purpose (PwC, 2013b).

In contrast to a much larger number of ex-ante HSR studies, ex-post HSR studies on wider impacts have been in scarcity. In the 1980s, early ex-post HSR impact studies largely focused on the Japanese and French experiences. These studies compiled a control group of places without HSR services, based on the comparison of economic performance (population, employment, property value etc.) before and after the introduction of the HSR services (Hirota, 1984, Nakamura and Ueda, 1989, Amano and Nakagawa, 1990, Sands, 1993) and tourism and service industries (Bonnafous, 1987). Since then, these descriptive statistical methods had been occasionally used to evaluate quite short term effects of large scale transport investment. The issue with these short term evaluations lies in a short-term judgment on those supposed to be much longer term impacts. Little wonder that the general picture is quite mixed (Givoni, 2006). Although some studies demonstrate faster growth rates of population and economic effects (i.e. employment and economic activity) for cities on HSR routes than those that are bypassed, some tend to be more reserved with insignificant findings e.g. Preston and Wall (2008). In recent years, a few ex-post studies attempted to examine wider HSR impacts at more disaggregated/multi-level, and long term HSR impacts e.g. Garmendia et al. (2008), Ureña et al. (2009), Murakami and Cervero (2010), Chen and

Hall (2011), Chen and Hall (2012).

In this paper we take a more detailed look at some ex post evidence for the impact of HSR on two key variables, output or gross value added in the regions linked by HSR, and the change in employment in knowledge-related sectors. We feel that this approach helps us to understand the process of change better than the ‘black box’ inherent in the aggregate studies and a better transition to ex post evaluation from the largely ex ante studies discussed above. We have focussed here on output and employment related data rather than the land-use approach used by Pugh and Fairburn (2008) for the reason suggested above that HSR has a more direct impact on certain sectors in specific locations than a highway improvement. Since HSR provides better links to those cities with stations than to wider regions we focus on evidence at the most disaggregated spatial level. The choice of knowledge-related sectors reflects the fact that HSR does not fundamentally change the transport costs for more traditional manufacturing industries, but does provide better connectivity for those working in those sectors where knowledge exchange is paramount.

This more detailed look at the performance of cities where HSR has been introduced complements the evidence in Cheng et al (2015) which showed how in city regions with HSR there had been interesting changes in overall employment structure. In Europe, specifically relating to the Paris-Brussels-Koln-Amsterdam-London network, the core city regions had grown more alike in structure and their hinterlands had also converged. In China, in the Pearl River delta region of Guangdong, there was less evidence of convergence. This suggests that, where HSR is introduced at an earlier stage of development it promotes divergence, but in more advanced economies it leads to convergence. This is entirely consistent with theories of economic development that suggest there is divergence in the earlier stages of development followed by convergence. It could be hypothesised that the introduction of HSR at a later stage serves to prevent fragmentation due to poor connectivity associated, for example, with congestion. We cannot through this evidence demonstrate that HSR is the cause of these changes, only that they are associated with the introduction of HSR.

The European network case study

In Europe, as in Japan, the early development of HSR was as often about creating new capacity on key routes as about reducing journey times. The potential for competition with airlines over medium distances of 400-600km was also a key policy objective to reduce airport congestion and provide a more environmentally sustainable mode for transport between large cities (Vickerman et al, 1999). France led the way in the development of HSR in Europe. The network has developed to link the major cities of France and also to the neighbouring countries of Belgium, UK, Spain and Germany. Particularly in the so-called PBKAL (Paris-Brussels-Koln-Amsterdam-London) network, the cities are ideally spaced at no more than 500km (Appendix Figure A1), although national borders mean that there are lower levels of traffic (and hence frequencies) than would be expected if the cities were within a single country (Vickerman, 2015). That wider region was the focus of the research reported in Cheng et al (2015). Chen and Hall (2012) have explored the impact of HSR on the Nord-Pas de Calais region (now part of the larger Hauts-de-France region) and especially the city of Lille.

In this paper we focus on the UK region of Kent and Medway on the London branch of the PBKAL network (Appendix Figure A2). The line, known as HS1, was completed in 2007 to provide new high-speed infrastructure between the Channel Tunnel and London St Pancras for international services. The region has two HSR stations at Ashford and Ebbsfleet with services to Paris and Brussels. In 2009 frequent domestic high speed services were introduced cutting the journey time from Ashford to London from around 80 minutes to 37 minutes with the new station at Ebbsfleet just 17 minutes from London. HSR services also use the traditional network to serve a wider range of towns and cities in North and East Kent producing valuable reductions in journey times and improvements in reliability. As Vickerman (2015) has identified, the more limited international services from the Kent stations has restricted the potential for basing development on these links, a point made in the review of ten years of operation of the Tunnel by Hay et al (2004). However, the introduction of the domestic services, not only enhances rail services to London, but also, due to the siting of the London terminus, to much of the rest of the UK through the adjacency of St Pancras station to Kings Cross and the proximity to Euston.

Impacts of HSR in Kent

Figure 1 shows the rapid growth of traffic on domestic regional services using HS1 since its completion in 2009. The performance of the Kent economy since the opening of the Tunnel is virtually indistinguishable from that of the South-east or England as a whole (Appendix Figure A3). This implies that there was neither a strongly positive nor negative impact of the Tunnel on the growth of GVA, as expected Kent was now performing like the rest of the wider region.

However, at a District level (Figure 2) we can begin to discern some interesting differences. Clearly Dartford and Ashford, the locations of Ebbsfleet International and Ashford International rail stations, have grown much more strongly than Kent as a whole. Only Dartford, which as well as having the HSR station at Ebbsfleet is located on the M25 London Orbital Motorway at a major crossing of the River Thames, exceeded the average GVA/head for England or the South-east. At the other extreme Dover has fared much worse than the average, particularly since 2008. This was impacted by the subsequent closure of a major pharmaceutical research facility at Sandwich in the District. Figure 3 re-presents the data from Figure 2 but using the start of domestic HSR services as the base (2009=100). This shows that Ashford has not performed as well since the introduction of domestic services as it has over the longer period. Perhaps the Tunnel effect was stronger than previously believed and the domestic services have served to support that growth but not change it fundamentally. The creation of opportunities at Ebbsfleet may, however, have had a stronger impact on Dartford.

Figure 4 shows the relative importance of jobs in the knowledge economy across Kent Districts in comparison with the South-east and Great Britain as a whole. Kent has a smaller proportion of such jobs than the economy as a whole although Districts such as Canterbury, Tunbridge Wells and Sevenoaks were all above the national average and the first two above the South-east average. The knowledge economy is defined using data from the Office of National Statistics Business Register Employment Survey as "*a group of specific sectors within the economy that are knowledge intensive in their activity, that deal extensively with information/information technology and whose business is all about the distribution or exchange of the information that they hold"*.

Figure 5 shows that in the period 1998-2008 Dartford had the largest increase in knowledge economy employment, but that Kent as a whole (excluding Medway) also showed faster growth than the rest of the country. Growth was also faster in the Districts with relatively low levels of such jobs. After 2008 the picture changed somewhat. Kent continued to show faster growth in such jobs than the rest of the country but the fastest growth was now in those with the higher concentrations, Canterbury and Tunbridge Wells, with Ashford also showing stronger growth in this period. It is not surprising to find that Canterbury, with three university institutions, has a high level of knowledge-economy employment, but the growth since 2008 suggests a high-speed rail effect may be present. The locations in West Kent such as Tunbridge Wells and Dartford also benefit from their greater proximity to London, with or without HSR, although interestingly Dartford showed lower growth in the period after HS1 was completed. The closure of the research facility in Dover led to a dramatic fall of more than 20% of such jobs in this period.

For most Districts in Kent, median earnings by workplace are lower than those measured by residence suggesting that out-commuting is more important than in-commuting. This suggests that the benefit of HS1 has been to encourage new residents rather than new businesses. Median earnings by workplace in Ashford are significantly below the national median, whereas for residents they are close to the median. Moreover, Ashford earnings are below the Kent averages for both workplace and resident measures.

The Chinese network case study

In comparison with Europe where rail infrastructure had been gradually modernised from the 1970s onwards, China did not do so until the 1990s by speed upgrading and its HSR network was not on the horizon until early 2000s. The Intermediate and Long-Term Railway Network Plan (hereafter ILTRN) was first published in 2004 by the Ministry of Railways (MOR, abolished in 2013) and later revised with a grand investment plan in 2008 when the first HSR line of 120 km between Beijing and Tianjing arrived just prior to the Beijing Olympic Games. The reaction to global financial crises was adopting a Keynesian economic approach by further infrastructure (including HSR and others) investment of 4 trillion yuan, which resulted in an even grander scale of HSR network expansion. In June 2016 the ILTRN Plan was further revised and updated to strongly reinforce the rail-led strategies of spatial development affirmed in the 13^{th} National Plan (2016-2020).

Improving accessibility for a size of country as large as China is critical. The aim is to make HSR connect all provincial capitals and cities of population over half a million, which will allow HSR network serving 90% of overall 1.2 billion population. The passenger dedicated lines (PDLs) are planned to link major provincial cities and large-to-medium size cities, comprising two major HSR systems i.e. criss-crossed PDLs across the country and inter-city PDLs around ten city clusters that serve more economically advanced and densely populated areas (see Chen (2012) and Yin et al. (2015)). The objectives manifested in the first HSR strategic plan of 2004 are far beyond accessibility to embrace rationales of modernisation competitiveness through a series of key strategies and actions including expanding network capacity for passengers and freight, rebalancing network inequality, extending international rail network, and fostering rail technological innovation and eventually exporting domestically developed technologies through international corporation and competition. This last objective is akin to the way the French TGV has become one of ten favourate brands of France (Pepy & Leboeuf, 2005) and “a symbol of modern society“(Arduin & Ni, 2005).

This paper chooses the Yangtze River Delta Area (YRDA)[1] as a suitable case for comparison **with European situations because the YRDA with** merely 2% of Chinese territory **generates 20.23% of National GDP is the most developed among three major mega city-regions[2]. This sheer scale of territory and population makes YRDA larger than most European countries. Sixteen prefecture-level cities** regarded as the core YRDA has more than 90 million registered residents and produced GDP per head **more than double of the national average (see Appendix Figure** A4). Most cities in the core YRDA have been served by new HSR **lines in July 2010 (see Figure 6 and 7). Prior to then, the major rail corridor in the YRDA was the conventional Beijing-Shanghai line that was upgraded to**

a maximum speed of 200 kph in 2004 and 250 kph in 2007. Current three of four non-HSR prefecture-level cities including Nantong, Taizhou and Yangzhou are located in "Middle of Jiangsu" that are less developed than South of Jiangsu. The situation will change in the foreseeable future since these three cities are scheduled to be connected with Shanghai by improved rail services while the fourth **non-HSR city, Zhoushan, is an exception because of its offshore location.**

Impacts of HSR in Yangtze River Delta

Since a comprehensive dataset of rail passenger traffic is not publicly available, an alternative approach involves a combination of various sources to notice the popularity of new HSR services and how that might have impacts on existing rail services. Appendix Figure A5 shows a progressive rise from 2000 up to 2008 and dramatic drop of rail passengers from 2008 on conventional Beijing Shanghai line while there had been a general trend of increase in rail passengers in these YRDA core cities over the year from 2000 to 2014. It can be argued that the popularity of new HSR services is reflected in the major shift from conventional rail to HSR services despite of early success of upgraded HSR in attracting more rail passengers. The declining trend was reversed in 2012 when the rail passenger volumes in many cities showed a steep rise, which can be regarded as a significant growth of rail passengers in general. By contrast, it is evident that non-HSR YRDA core cities presented in the bottom of the diagram show their numbers of rail passengers over the years stagnated.

The arrival of upgraded HSR services in the core YRDA dated back in 2004 and the new HSR lines 2010 onwards. In order to compare impacts among core YRDA cities, 2005 was selected as a time node because it was the earliest year when the statistical data are publicly available in different cities under study. Moreover, by choosing three time-series (2005, 2009, 2014), it allows comparison between upgraded HSR (2005-2009) and new HSR effects (2009-2014). Similar indicators to those adopted in the European case were drawn on to measure economic changes, including changes in economic output (GDP), population, employment and economic structure both aggregate and disaggregate spatial levels. All the statistical data are sourced from statistical yearbooks at different levels of government involved.

Firstly, Gross Domestic Product (GDP) is used as an indicator of economic performance because Gross Value Added (GVA) figures are not available in China. In Appendix Figure A6, two diagrams are juxtaposed to signify the impacts of HSR on economic performance among China, YRDA, and core YRDA. China, as a fast-growing emerging economy, demonstrated stronger economic growth than relatively developed regions (both YRDA and core YRDA). The difference between the two diagrams lies in the selection of the reference year. If GDP in 2005 is set index of 100, the arrival of HSR (either upgraded or newly built) did not seem to have transformative effects. Whereas a different picture is unveiled when 2010 (GDP=100) as the reference year is used (see the bottom diagram). After the arrival of Shanghai-Nanjing HSR line in 2010, the core YRDA had performed remarkably stronger than YRDA and national performance. The performance gap between core YRDA and YRDA as a whole appears widened. Such finding critically highlights the importance of differentiating particular events in time in order to discern possible impacts. Moreover, we also take heed of a development pattern shown in fast growing economies that the more developed an area is the relatively lower economic growth rate it shows while being compared with other less developed areas. Therefore, when the core YRDA outperforms YRDA and China after the arrival of HSR, this could be regarded as a key structural force that overtakes the general trend.

A similar pattern that more developed places show a slower growth rate than less developed places is also found at the prefecture-city level. Appendix Figure A7 shows that all YRDA core cities had grown remarkably from 2005 to 2014 (GDP 2005=100) and that no apparent fluctuation of economic performance occurred as seen in Kent districts. The largest growth took place in three "Middle of Jiangsu" cities (index 400 shown in Taizhou of Jiangsu) while Shanghai, the largest and most advanced city in the YRDA had the relatively lowest growth (index 250). Likewise, the impacts of new HSR lines could be better identified when the economic base changes to 2010 (GDP=100) (see Figure 8). Again, all core cities in YRDA showed considerable economic growth. The three non-HSR middle of Jiangsu cities did not perform at the top of league since 2010. Nanjing performed the most impressively (2014 GDP index nearly 170) stronger than the core YRDA average. Shanghai remained at the bottom of the league with nearly 140 (growth index) in 2014 against 100 in 2010.

Secondly, since China is undergoing rapid urbanisation through rural-urban migration on the national scale, understanding population change is a useful indicator to perceive HSR impacts on job creation in places that can attract more residents whose registered residences are elsewhere. Two useful inter-related indicators are registered residence and permanent residence[3]. A place with more permanent than registered residence can be regarded as a more economically attractive place than a place that has a larger registered than permanent residence. Appendix Figure A8 clearly shows a generally higher permanent residence than registered residence in YRDA core cities except three non-HSR cities in Jiangsu province. Moreover, Figure 9 further displays that for all HSR cities, the growth in permanent residence was stronger after the HSR arrival than the earlier period of upgraded HSR service whereas three non-HSR cities appear to be more disadvantaged at losing permanent residence. However, employment change (see Figure 10) presents a much mixed picture. Although generally HSR cities show employment growth over time, the growth during 2005 and 2009 was stronger than the period during 2009 and 2014. Some HSR cities have shown decline in employment after 2010 such as Changzhou and Huzhou. Within three non-HSR cities, Yangzhou shows employment decline whereas Nantong and Taizhou have very minor increase in jobs. More in-depth research is needed to explain what the cause is. Having said that, Suzhou and Shanghai have shown the largest growth in employment during 2009 and 2014. It implies that the arrival of HSR co-related with the enhancement of a few key cities in core YRDA. One can argue that the proximity of Suzhou to Shanghai by HSR is making Suzhou a much more attractive place for work and residence.

Thirdly, concerning changes in knowledge economies, similar approaches to the Kent case were adopted. Due to different contexts between post-industrial Europe and rapid industrialisation in China, secondary industry is also analysed to perceive possible differentiations of HSR impacts between the two contexts. Figure 11 shows knowledge economy has higher presentations in Shanghai, Nanjing, and Hangzhou in 2014. Except these three cities as well as Zhoushan which is an offshore prefecture-level city, all the rest core cities in YRDA had secondary industry accounting for more than 50 % of employment structure. Examining the changes in knowledge economy, Figure 12 shows that before the arrival of HSR (2005-2009), the picture of economic structural change was rather mixed. Largest increases in knowledge economy appeared in Changzhou and Shaoxing, two relatively small HSR cities in comparison with Shanghai and provincial capitals, Nanjing and Hangzhou. Even Shanghai had more growth in secondary industry than knowledge economy. After the arrival of new HSR lines, growth in knowledge economy appeared strongest in a few major cities such as Hangzhou, Shanghai, Nanjing, Suzhou, and Ningbo while Suzhou showed growth in secondary industry too. Two non-HSR cities Nantong and Taizhou in Jiangsu province had apparent growth in secondary industry in contrast to decrease in knowledge economy.

In the previous sections, Suzhou has demonstrated its economic growth and strength in the rise of permanent residence and job creation after the arrival of HSR although the growth is not only shown in the percentage of knowledge economy but also secondary industry. The question then raised is whether benefits are spread into surrounding sub-regions or concentrated around its core sub-region. To answer this second question, Suzhou (city region) is a good case for a more disaggregated analysis at the sub city-regional level - whether the benefits brought to Suzhou city region could be redistributed and spread widely into a wider city region.

Appendix Figure A9 offers a map showing the sub-division within Suzhou and the rail links within Suzhou city region and Shanghai. Apart from Suzhou urban districts that are served by four HSR stations, Kunshan is the only county-level city with three stations served by HSR. Suzhou urban districts and Kunshan showed larger employment volumes and faster growth in both population and employment in contrast to an apparent gall in other non-HSR sub-regions (see Table 1). Regarding economic restructuring, Figure 13 and 14 showed varied impacts among sub-regions, which is indiscernible when Suzhou city-region as a whole is analysed. The most striking of all is Kunshan's strongest growth in secondary industry and least in knowledge economy amidst the remarkable growth in population, GDP, and employment. By comparison, non-HSR sub-region Taicang showed its growth in GDP and knowledge economy than the Suzhou city regional average. Two points can be made here for preliminary explanations. First, Kunshan has been drawing on its locational proximity to Shanghai as a growth strategy in successfully attracting secondary industries which could not be located in Shanghai (Chien, 2007). Secondly, both Kunshan and Taicang with their geographical advantages of being adjacent to Shanghai, in recent years, have further enhanced their transport connections with Shanghai (Wu, 2015). Active interventions in attracting industries and enhancing transport network seem to work well in generating spillover effects from Shanghai into neighbouring places. More research will be entailed for further in-depth analyses.

Discussion

The main question posed at the outset was whether HSR, which dramatically enhances the accessibility between cities, will reduce or increase the economic disparities between those cities? Furthermore, can it effect a transformation in the economic structure of the regions connected or does it widen inequality? In both regions there is a mixed picture, but HSR appears to strengthen most HSR cities and not necessarily at the expense of non-HSR cities. This is seen most clearly in the growth in the knowledge economy.

However, the comparison of the two regions highlights that the role of HSR varies in different contexts. In particular there are distinctive economic trajectories e.g. YRDA, albeit the most advanced and quite diverse region in China, is still dominant in secondary industry in contrast to post-industrial Europe where secondary industry has largely moved out to industrialising countries. Since doubts have been cast on the mismatch between the strategic role of HSR in strengthening post-industrial Western Europe in its knowledge economies and the current economic trajectories in China (Chen, 2012), this new evidence is significant because it shows that in Europe, HSR mostly appears to assist the division of service labour between routine and knowledge-intensive activities whereas in China, in addition to this HSR potential for developing the knowledge economy, HSR has the potential to facilitate division of labour between manufacturing and the service sector. Most HSR cities are still dominant in secondary industry such as Suzhou (in particular its sub-region Kunshan) and Wuxi. With the arrival of HSR, manufacturing factories can be more easily decentralised for cheaper land and other costs whilst operations can be sustained by managers who take HSR for internal communication with parent companies and external activities among different firms. The high-frequency HSR services between various YRDA cities have begun to shape economic operations in this region and encourage more interaction between them. A HSR passenger survey (Wang, 2016) showed that about 61% of HSR trips were business-oriented, of which 34% were for internal communication within companies such as training and instruction activities and 66% for external contacts with other companies for deals, research and development, marketing and promotions. This difference echoes and illustrates further the argument of Cheng et al. (2015) on the convergence and divergence at different stages of economic development.

Non-HSR cities experienced much stronger economic growth in terms of overall GDP and a growth in secondary industry. This point is especially demonstrated by the lowest growth of GDP per head in Shanghai among all core YRDA cities. It is reasonable to argue that these places are still under rapid industrialization and many other investments contributed to the growth beyond HSR.

Moreover, with the disaggregated approach examining at the intra city-regional level, findings in Suzhou city region present a more negative/unequal picture than districts in Kent County. Two factors can be involved for explaining this. Firstly, there is no administrative body and statutory planning power to consider the wider effects of HSR at the city-regional level. Rather, Suzhou city region is vested with power to maximise fiscal extractions from surrounding sub-regions because Suzhou Prefecture-level city that includes Suzhou urban districts and four sub-regions (county-level cities) reflects a "city-leading-county" administrative system (Ma, 2005) through administrative restructuring and annexation that promotes "inflated urbanisation" (Chung and Lam, 2004, 945). Likewise, there is an administrative fragmentation at the strategic level due to an overlap of regional development remits in YRDA designated to three central government departments (Wu, 2015). Although HSR is claimed to assist regional economic integration between cities, in reality, despite similar sounding strategies, many cities use it to promote competition more than collaboration. The Pearl River Delta Area has a similar situation. Xu (2008) argued that current practice can be understood as an important structural and strategic expression of locally and regionally articulated processes, which might be "little more than a cosmetic makeover that hides the intensifying competition within major city-regions in China" (ibid, p.157). Hence, it is difficult to address the inequality without a proper governance structure, an issue that is commonly shared by many other cities and regions in China. A similar lack of cooperation between the districts within Kent could also be argued to have had the effect of preventing full exploitation of the greater connectivity provided by HS1.

Secondly, apart from the lack of an administrative structure at more strategic levels that could somehow address intra-regional polarisation, the distinct characters of the rail networks between the two regions also contribute to the widened intra-regional inequality in the Chinese example. In Kent and some other European regions, rail stations are mostly built with a reasonable size, located in the city centre with easy access from elsewhere. HSR and extensive conventional rail networks interoperate to serve the wider territory, which means that hinterlands can also benefit from HSR services in general although they might not have high-speed rail stations. The arrival of HS1 in Kent in 2007 was followed by the introduction of domestic HS1 services in 2009 that are aimed to benefit Kent County more widely after the arrival of HS1. Whereas in YRDA and China in general, the territory is vast while the density of rail network is very thin in comparison with Europe. In addition, many HSR stations are generally large-scaled, located in the outskirts of cities, serving limited dimensions of rail flow despite vast volume, and lack sufficient connectivity with other levels of public transport systems (Chen et al., 2014).

The distinct nature of rail network aforementioned further explains how differently HSR changes people's life in China and Europe. Over past thirty years, HSR services in Europe, in particular for a one-hour train time between two cities, tend to encourage daily commuting and economic development such as French TGV experiences (SNCF, 2011) and InterCity 125/225 in the UK (Chen and Hall, 2011). In this circumstance, the socio-economic geography as to where people live and where people work is more flexible and complex. In the case of Chinese HSR services, daily commuting is still unlikely to be a normal practice. As Wang (2016) shows in the HSR passenger survey in YRDA that the frequencies are mostly once a week or twice a week due to the large scale of cities and considerable amount of travel time spent on accessing and egressing enlarging urban transport systems due to urban expansion. For instance, the train time between Suzhou and Shanghai HSR stations is about 30 minutes. However, the travel time from an origin home in Suzhou to one of Suzhou HSR stations takes normally one hour by public transport and another one hour from Shanghai station to a destination in Shanghai. Altogether the train time is just one fifth of the overall journey unless the destination and origin are just next to the rail stations, which is rare. As a result, although there is the dramatic change in inter-city accessibility between HSR stations, there is a huge gap between HSR train time and the door-to-door journey time, which causes lots of serious issues in integration, interchanges and urban accessibility to and from the stations (Chen and Wei, 2013; Hickman et al., 2015).

Lastly, we also come to realise that researching differences in models of development following HSR arrival between Europe and China could allow us to explore more widely what kinds of transformational effects are most welcome, achievable and desirable, given the fact that in different regimes developmental imagination led to completely different outcomes so it is difficult to judge them comparatively. On the one hand, in Europe, at the appraisal stage, an investment as large as HSR will be debated and scrutinised by a series of feasibility and justification appraisals. For instance, the wider effects of HS2 in addressing north-south divide in the UK have triggered the great divide is the latest example of this situation (Hall, 2013). In the developmental process, in Kent, for many years no obvious development projects are taking place around the Ebbsfleet HSR station until more recently. On the other hand, in China, the development of HSR network is a key national transport policy and spatial strategy which also fits well with local urbanisation and development strategy. Although the current practice of HSR stations in China tend to be located outside city centre, HSR is envisaged with a new modern central business district with high-rise office blocks. A new town concept is established optimistically with the HSR arrival, just in a couple of years, new buildings are built in the belief that once they are built, development will come (for more about the Chinese style of creating new cities, see Shepard, 2015). Suzhou North Station in the Xiangcheng district is a typical example. This development model is characterised and supported by government-led financing and land selling systems. Consequently, new physical transformation around the station seems to be achieved quickly but in reality, in most cases, tenants of these buildings still do not exist until later stages while incentives kick off to attract them. Many of these scenes are called "ghost towns" since there are no other activities taking place except the stations' transport function. Once the boundary of this new town area is announced publicly, the landscape begins to enter a transitional stage because of uncertainty and speculation. Many traditional rural settlements are demolished for land sales and villagers are asked to move and could not be relocated back. Many buildings are torn down and some still remain in pieces. Many social problems are derived from this development phenomenon (Wu, 2015). All these rapid practices in China actually create more questions than answers, namely how much time will be needed to allow transformational effects? Does it make sense to pursue physical or economic transformation while ignoring social justice and environmental issues? Through this comparative study of the two cases, there is a real danger to either underestimate or overestimate wider HSR impacts.

Conclusions and implications for the future

In this paper we have tried to go beyond the usual measurement of economic impact as GDP/GVA change and growth to consider how the transformational impact of new transport infrastructure, especially HSR, impacts on economic structure. This is also consistent with how the aggregate analysis has moved from simple definitions to more complex definitions of accessibility to a greater concern with connectivity. How businesses connect with each other, how businesses connect with labour and how individuals and families connect with each other are critical to the understanding of how HSR impacts on cities and regions. In this we have both taken the understanding a step forwards, but also identified a number of challenges for future research.

By comparing two regions we have shed some further light at the more localised level on the trends noted in Cheng et al (2015). Regions at different stages of development respond to the introduction of HSR in different ways. The more advanced the regional economy the more HSR seems to promote convergence both between cities on the HSR network and between those on it and those off the network but dependent on those on it. In a less economically advanced region, the introduction of HSR may lead to greater sectoral specialisation that may lead to convergence in aggregate performance but less convergence in economic structure. We have explored this in terms of employment in the knowledge economy, but further research into skill and occupational structure changes is needed, since it is at this level that connectivity is most significant.

In both cases there is evidence that regions and individual cities within them may not have gained the full advantage that a place on the network could have generated. Failure to understand the importance of connectivity between the HSR network and more local networks, failure to develop HSR stations fully within the urban infrastructure and failure to put in place complementary urban land use planning all diminish the potential impact of HSR. Moreover, this comparative study clearly indicates different local conditions, economic trajectories, and different national approaches play key roles in explaining transformational effects. A better understanding of how HSR will relate to the local economy and how it could help to transform it is key to whether HSR can in any sense be transformational.

This leaves the question of whether and how such potential effects can be included in any investment appraisal of new HSR lines. The analysis above suggests that there is no simple measure of wider economic impacts that is appropriate to inter-urban HSR projects of the type used in urban projects based on effective density or economic mass. A much more nuanced analysis looking in detail at economic structure and the effect on this of changes in connectivity is needed. The primary conclusion is that HSR can transform regional economies, but this transformation is not automatic or guaranteed and can take different forms in different circumstances.

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Notes

[1] The boundary of the YRDA has been defined in different ways. The most widely accepted definition is to include Shanghai and two provinces Jiangsu and Zhejiang. A wider YRDA tends to include Anhui province. If Anhui is further counted in, a wider YRD covers an overall area of 350000 km^2.

[2] Figures are sourced from China Statistical Yearbooks.

[3] In Chinese statistical yearbooks, a figure of "permanent residence" in a place refers to number of residents living in a place more than 6 months and excluding residents who do not live in a place in the recent 6 months. Thus, permanent residence actually reflects a more updated pattern of development than registered residence. However, it is also true that the term "permanent residence" given as an official English term by default in Chinese statistical datasets appears confusing.

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