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Citation for published version

Vickerman, Roger W. (2017) Beyond cost-benefit analysis; the search for a comprehensive evaluation of transport investment. Research in Transportation Economics, 63 . pp. 5-12. ISSN 0739-8859.

DOI

https://doi.org/10.1016/j.retrec.2017.04.003

Link to record in KAR

http://kar.kent.ac.uk/61779/

Document Version

Author's Accepted Manuscript

Beyond cost-benefit analysis; the search for a comprehensive evaluation of transport investment[1]

Abstract
Major advances have been made in trying to go beyond the conventional cost-benefit analysis appraisal of major transport projects that focus almost entirely on user benefits. Whilst newer methods to estimate the potential for agglomeration impacts in an imperfectly competitive world have become more mainstream there is still a desire to be able to capture more robustly the even more transformational impacts that are often claimed to result from major projects. This paper reviews some of these approaches and discusses how they have been used in some projects in the United Kingdom. It concludes that there is still scope for further improvement but that the desire of policy makers for precise estimates may have to be modified.

Keywords
Infrastructure investment; cost-benefit analysis; wider economic impacts; high-speed rail

Introduction
Cost-benefit analysis (CBA) has been the mainstay of the appraisal of transport investments for at least the past fifty years, though its origins go even further back. Throughout this time there has been a debate about the appropriateness of CBA as a means of evaluating projects and of choosing between alternatives. The main elements of this debate fall into two broad areas: what is included and what is left out; and what values should be imputed to those elements where either there is no market price or the market is distorted such that any observed price does not reflect the true resource value (see de Rus, 2010, for a useful overview and Priemus and van Wee, 2013, for a discussion in the context of large-scale projects).

For many years CBA was restricted to those elements that could be observed and quantified reasonably easily, if not in an actual market at least in a surrogate market. Thus elements such as time savings, the cost of accidents and noise pollution were included, but wider environmental effects, visual intrusion and such elements typically left out. This left one major area of contention, the impact on the economy. It is known that transport improvements that change accessibility can have important impacts on land values, but these have typically been excluded because of the danger of double-counting the accessibility change reflected in time savings with the resulting impact on property prices. This was taken as a warning not to try and inflate the benefits by including what were in effect alternative measures of the same thing. However, the problem that was often hidden was the implicit assumption that whatever was going on in the transport markets, the rest of the economy was in a state of perfect competition with constant returns to scale. In such a state, where prices were equal to marginal costs, the exclusion of these perceived secondary benefits was correct since any change in transport 'prices' would be reflected in

[1] An earlier version of this paper was presented at the NECTAR Cluster 1 Workshop on 'The Wider Economic and Social Impacts of Transport Networks, Molde, Norway, May 2016. The author would like to thank the participants of the Workshop for comments; the editor and referees for their careful reading of the paper, for pointing out errors and ambiguities and helping to improve the argument of the paper. Any remaining errors and ambiguities are the responsibility of the author.

an equal change in the prices in the affected market. But, as highlighted by SACTRA (1999), following the insights of Krugman (1991), once the transport-using markets were in a state of imperfect competition, where increasing returns to scale were possible, this assumption was no longer valid, and hence it was legitimate to try and identify the existence of additional economic effects.

This also relates to a further debate. The traditional approach is based firmly in a welfare economics framework in which the primary objective is one of maximizing net benefits/consumer surplus. More recently the focus of policy makers has switched to an objective of the output or employment arising from transport improvements. This is equivalent to the move from a world of perfect competition in which welfare and output were broadly equivalent to the imperfect world in which they could diverge. Under this approach the focus will be much more on the impact of changes on the productivity of resources than on the attempt to value the welfare benefits from time savings. Thus impacts on gross domestic product or gross value added, at both local and national level have become the focus of debate. In particular the question of redistributive versus net impacts has come to the fore.

In this paper we take up these themes looking first at the standard and then the extended cost-benefit analysis model with a view to assessing their limitations. We then turn to the inclusion of wider economic impacts, but essentially as an add-on within the broad framework of the CBA model, before examining whether it is possible to approach the problem from a different direction to avoid the limitations of the CBA framework. That different direction is to look directly at the impact on value added or employment rather than inferring this from the welfare changes addressed by the more conventional approach. The paper concludes with a comparison of some ex ante and ex post evidence from various major projects to illustrate the argument.

Issues in the Standard CBA Model

There is no universal standard CBA model, most countries define their own specific requirements for appraisal, but most follow a similar set of criteria (see Annema, 2013, for a comparison of approaches). The UK uses a standard format summarised in a web-based platform WebTAG (Department for Transport, 2014). This defines all the inputs required for an appraisal and the current values of the standard parameters such as time savings, accident cost savings etc. At the heart of any such appraisal is the forecast of traffic with and without the scheme so that a comparison can be made with scheme against a base case of what would be the situation if no scheme were adopted. It is important to note that the base case is not the current situation. In some cases, there may be various alternatives to be assessed and compared.

Forecasting traffic for most schemes depends on a variant of the conventional four-stage transport model: generation, distribution, mode split and assignment. Frequently this is simplified to use a fixed trip matrix so that the overall volume of traffic is kept constant and simply reassigned between destinations, modes and routes as relative costs change. This is appropriate for urban schemes where the peak-load traffic is given by regular commuting trips and an individual scheme is not going to prompt relocation of workplaces or residences to any great degree. It is less appropriate for larger and inter-urban schemes that change

both global and relative accessibility and where peak-load traffic is made up of people making less regular journeys such as those for business or leisure.

There have been several studies that have shown the extent to which, especially for large-scale projects, traffic forecasts have been shown to be inaccurate to a degree that compromises the ex-ante evaluation of the project (Flyvbjerg et al. 2003, 2006). But such studies focus on the macro-financial aspects of projects. These raise questions about financing projects and risk and resurrect the concern about crowding out of private investment that was the focus of Aschauer's original contribution in this area (Aschauer, 1989). In a recent paper (Ansar et al, 2016) apply such concerns to an examination of recent Chinese investment in infrastructure and conclude that it has contributed little if anything to Chinese growth which, if traffic forecasts have not been achieved or costs have exceeded estimates, a project will fail to meet its financial targets and in consequence is seen to place an expected drain on public funds that could impair economic growth by starving potentially more profitable projects of funds. This ignores the extent to which the project may have made a contribution to that investment or promoted economic growth independently of realised traffic. Moreover, the time period chosen to assess a project's performance may be too short to realise all the potential economic impacts. The main lesson from our critique of this approach is that examining traffic forecasts alone may not be the most useful indicator of a project's success.

This goes to the heart of the standard CBA approach, which focuses primarily on traffic, since user benefits dominate the welfare gains through time savings and lower accident costs, plus congestion and reliability effects. Whilst standard valuation methods have been developed for these welfare gains, increasingly they have come under scrutiny. Whilst fairly consistent estimates for the value of travel time savings can be derived from a variety of methods, both revealed and stated preference, the key question remains as to whether such time savings can be reinvested into welfare producing activities and, particularly when it comes to business travel savings, into productive activities. This is not the place to conduct a full review of alternative methods of valuing time-savings (see, for example, Hensher, 2011, for a review), but we focus on one issue that has come to the fore in the appraisal of major projects, the value of business time savings.

The criticism of standard approaches to business travel time savings, which are valued typically at around three times those of leisure time savings and hence close to the real wage of such travellers (whose wages are also typically much higher than the population at large) is that such values overestimate the potential savings in an age of mobile communications. Here it is argued that if business travellers can maintain contact throughout a journey as well as work on laptops, tablets etc., saving time on a journey has little or no value. Since big inter-urban projects are heavily dominated by business travellers, reducing their value of time savings could reduce the perceived value of a project significantly. Whether this argument holds therefore depends on the extent to which travellers can work effectively whilst in transit. It is clear that this is not a question to which there is a definitive answer. Whilst working on a train, for example, are business travellers being fully productive; can they work effectively, are they compromised by the lack of privacy etc.? Whilst it may be difficult to defend the values of business time savings

currently used, it may be equally difficult to determine by how much they should be modified.

Some critics go even further, suggesting that conventional travel has a limited lifespan due to a move to increasingly virtual contact. In such circumstances there would be no place for time savings as virtual communication would dominate. This seems extreme in the lifetime of most current projects. Most business deals need face to face contact, certainly in dealings above a certain value and the increasing mobility of individuals implies growing, not diminishing travel for social and family contact as well as longer distance commuting (including weekly commuting patterns). One only needs to look at the importance of visiting friends and family in most travel diary surveys to see how the globalisation of labour markets and other opportunities has impacted, not just on urban travel patterns, but also on international travel. Improved communication is not always a substitute for travel but is actually a complementary good enabling the easier arrangement of meetings. Mohktarian 2003 and Choo et al (2007) have shown, through a detailed analysis of expenditure patterns, that in a more general sense, travel is not a clear substitute for other forms of household spending.

The activities undertaken through this travel may be difficult to evaluate in terms of conventional measures of welfare using values of time savings as a proxy, but they are clearly likely to have an impact on output, jobs and growth. Can these be introduced effectively in an extended CBA framework?

An extended CBA Model

SACTRA (1999) identified a basic argument for how extensions could be made to provide a more complete CBA model. In part these were to incorporate various external impacts in the same broad framework. Hence it is possible to allow for environmental impacts to be evaluated in monetary terms along with the direct impacts on time savings accident costs, etc. Most of the extensions have dealt with these negative impacts, but increasingly there has been an interest in identifying potential positive externalities, of which the impacts on jobs and growth have been to the fore. The fear is always that such impacts may imply double-counting of benefits. If transport users value time savings because they enable easier access to better jobs, and the reduced cost of travel increases access to labour markets, then it would be wrong to add some benefit of increased employment to the existing savings.

However, this depends on the key assumption that labour markets, and indeed all markets, are perfectly competitive such that the fall in the cost of transport is reflected wholly in prices in the markets using that transport. When there is imperfect competition there is a wedge between the price change in the transport sector and the impact of that on prices elsewhere in the economy. This is similar to the tax wedge that leads to problems in the use of wage rates to estimate the value of time savings (Venables, 2007). In an urban context, the impact on labour markets, through improved sorting or increased participation rates, is fairly clear. The effective density or economic mass of a location is enhanced through access to more and better labour/employment opportunities. But in an interurban context, such as the investment in a high-speed rail link between two cities, it is less immediately clear. The regular commuting use of such a link is likely to be less significant than in the urban case,

although is used by some opponents of such projects to argue that all the potential benefits will be captured by the more dominant, core, city. Clearly models developed for application in large cities cannot easily be transferred to inter-urban situations where account will need to be taken of relocation effects, including the impact on travel in course of work (business travel) and non-work travel. In an imperfectly competitive world it is likely that such impacts will outweigh any potential double-counting effects as will be shown later in a discussion of alternative methods.

Imperfect competition effects are not just about the labour (and other) market effects relating to the use of market prices, but also the extent to which firms, for example, can use changes in the prices of inputs such as transport to change the mark-up, either to increase profits or to attempt to increase market share. This is a core observation of the new economic geography theories following Krugman (1991). But, as Venables et al (2014) have shown, it is important to distinguish the various elements of what are sometimes simply lumped together as wider economic impacts.

An extended CBA model focussing on welfare impacts needs, not just to take into account the fact that there are externalities, but also to allow for the distribution of costs and benefits. This distribution is both about the impacts on different groups in society and the distribution between different time periods. The latter is essentially a debate about discount rates and rates of time preference. The former often comes back to debates about appropriate values of time savings when these are related to wage rates. Van Wee (2012) has discussed these equity issues in more detail in relation to how decisions are made based on CBA. Essentially he discusses whether and how CBA can lead to democratic decisions. This is a critical issue as increasing the complexity of CBA can lead to alienation or exclusion of groups from the decision making process. Moreover, the increasing complexity and cost of such analyses may present objector groups with a difficulty in mounting effective opposition to a project or putting forward modifications or alternative solutions on a level playing field.

Modelling economic impacts

There is a long history of attempts to relate transport infrastructure to economic growth and development. This is not the place to rehearse all the arguments but essentially we can identify three broad approaches: macroeconomic, microeconomic and new economic geography. The macroeconomic approaches relate broad aggregates such as expenditure on infrastructure to aggregate economic performance through an augmented production function. The basic argument goes back to the work of economic historians such as Fogel (1964) and has its major reinforcement in the work of Aschauer (1989) and the subsequent range of studies attempting to reinforce or disprove Aschauer's basic premise. What Aschauer claimed to have demonstrated was that there was a productivity impact of infrastructure expenditure which outweighed any crowding-out effect of public expenditure on the productivity of private capital. The primary problem with such aggregate studies, aside from the econometric problems, is that the direction of causality is not always clear (Gramlich, 1994). Whilst new infrastructure may not directly lead to accelerated growth, its absence may be a constraint on such growth.

Arguing about the econometric issues or causality in macroeconomic production function models may be useful in determining the relative efficacy of infrastructure versus policies to encourage private investment or enhance labour productivity, but is not of any great benefit in the appraisal of individual investments in infrastructure. Ansar et al (2016), have, for example, argued that Chinese investments in high-speed rail have not been successful in delivering growth to the Chinese economy and indeed might have limited longer-term growth through an increase in indebtedness. However, this does not mean that investment in high-speed rail has not had profound impacts on the economy nor that individual cities and regions could not have benefitted overall (see Chen and Vickerman, 2016, for some evidence). One conclusion that is, however, clear is that beneficial impacts of transport infrastructure investment in one location cannot simply be transferred to imply they will have similar impacts anywhere else. As the Biehl report to the European Commission (see Biehl, 1991, for a useful summary) argued, transport infrastructure investment can only benefit a region if the existing provision of transport is inadequate such that it acts as a constraint on development. Hence investment in transport in already prosperous regions may be more useful than in lagging regions; policies to equalise infrastructure provision across regions may be counterproductive.

This highlights the importance of understanding the microeconomic relationships of transport within a local economy. Aggregate production functions cannot identify the way a region's industries use transport. This is not just a question of sectoral structure of a regions' industries as such factors can be allowed for in aggregate production function approaches. It requires knowledge of the location of markets for both inputs and outputs and the competitive structure of each sector. Many sectors in many regions have adjusted the way they produce and hence compete to allow for locational disadvantage. This is the key insight of the new economic geography approach. In effect transport is a substitutable input and lowering transport costs in a location that has other clear cost advantages may have limited impacts on the local economy.

But there can also be in-firm changes that affect the way that transport changes are used. Venables (2013) has argued that agglomeration impacts may be more important at the level of skills and occupations than at the more aggregate level of the sector. Thus with better communications firms may choose to concentrate particular activities in a location, whilst keeping a presence in several locations. Evidence from France suggests that such processes were at work in response to the first TGV lines (Plassard and Cointet-Pinell, 1986; Klein and Claisse, 1997). Whilst this process can be observed ex post, it is more difficult to establish ex ante whether such responses are likely and the balance of any changes on the local economies of the affected regions. We return to this question later.

The approach which has offered most potential in combining these various issues with a tractable model is that of the so-called new economic geography following the seminal work of Krugman (1991) and brought together in a fuller analysis by Fujita et al (1999) (see also Lafourcade and Thisse, 2011, for a valuable summary of the state of the art). The essence of the approach, which originates in trade theory, is that, in a world of imperfect competition not characterised by constant returns to scale, the trade-off between transport (trade) costs and market size can lead to differing outcomes according to the initial values of these elements and the degree of change of the costs. Hence, a given change in transport costs

could be either centralising (activities move towards the larger city or regional economy) or decentralising (a movement towards less inequality between the affected economies) according to the starting values. This suggest there is no unique relationship between accessibility and agglomeration.

The lack of an analytical solution to the theoretical model of the new economic geography, but its dependence on numerical simulation to provide insights, seems to preclude its usefulness as the basis for appraisal. However, using disaggregated data on firms, it has been possible to derive empirical tests of the basic predictions (see, for example, Combes and Lafourcade, 2005, 2011). For ex ante evaluation, Venables (2007) outlined the relationship between productivity and city size. Graham (2007) used this to estimate the relationship between the change in the effective density (or economic mass) of local labour markets and productivity. Graham observed that the elasticities in a metropolitan environment dominated by service sectors were generally larger than the elasticities traditionally observed between city size and productivity where manufacturing industry dominated (see for example Glaeser and Gottlieb, 2009). The approach used by Graham has become the basis for the estimation of the agglomeration elements in wider economic impacts used by the UK Department for Transport (2014). This approach has been reviewed and endorsed by Venables et al (2014).

The key point to note about this empirical use of the new economic geography concept is that it is based on firm level data so captures a higher degree of specificity than area-based data. But it still presents problems for ex ante evaluations. Estimates of parameters derived in one case may not be directly transferable between different projects in different locations. Moreover, there is an assumption that the behavioural response to a given change in transport costs is also transferable. This latter point is critical as most transport appraisal has been carried out on the basis that users' responsiveness to changes remain constant. Frequently this involves the use of evidence collected from previous changes that are often relatively marginal, whereas large projects typically involve non-marginal changes in generalised costs, particularly the time element. Even allowing for this marginal versus non-marginal issue, large prestige projects may change users' perception of time and distance such that there are significant changes in behaviour. This may be partially predictable: large changes or the culmination of a series of small changes may reach a tipping point where, for example, relocation takes place. This type of behaviour is predicted by the possibility of discontinuities in the new economic geography model leading to bifurcations where a gradual process of, for example, concentration, suddenly flips and convergence dominates.

There remains the question of what economic impacts should be taken into account. The traditional appraisal approach has been based on the concept of economic welfare which is usually expressed in terms of a measure of consumers' surplus. This has the advantage of being easily expressed (and illustrated) in terms of the traditional demand curve following the work of Marshall (1920). The problem with the consumers' surplus approach, however, is that it is essentially a partial equilibrium approach assuming, typically, a perfectly competitive world with constant marginal costs. Aside from the issue of whether assumptions of equilibrium are appropriate, it is the way that traditional appraisal based on this approach ignores the interactions of the changes in the transport sector with the rest of

the economy that causes most problems. Interestingly, what is often thought to be the parallel development of economic surplus by Dupuit (1826) can be argued to be much more comprehensive in its observations as to how a change in transport may change the nature of the goods carried and where they are carried to and from (see Rothengatter, 2017, for a reappraisal of Dupuit).

Increasingly, however, policy makers have become less interested in welfare measures, given their degree of abstraction, and more interested in impacts on output (GDP or GVA) or particularly employment. Thus transport investments become less about increasing the welfare of users and more about creating jobs in the places served. More widely than that it begins to focus on the way that transport changes change the accessibility of places, and perhaps also the perception of that accessibility or connectivity to the rest of the economy. This impacts on productivity, which should be the key focus of this approach, and such a focus is less likely to lead to policies that result simply in the redistribution of activities between locations.

From accessibility to connectivity

At the core of most transport investment appraisal is accessibility. The basic premise is that improved accessibility implies lower transport costs that in turn increases the value of the activity needing the transport. But most measures of accessibility, whether using distance or time as a base, imply continuity and an equivalence in value between different broad groups of activity. This ignores the extent to which different activities may use transport very differently and hence a given improvement in accessibility may have very different impacts in different circumstances. Vickerman et al (1999) identified how measuring the accessibility impact of high-speed rail in different ways could imply differential impacts. In part this depends on whether the change can be used effectively, for example by making a return journey possible in a day with a useful period of time at the destination. This may also depend on hitting certain headline journey times such as 2 hours making destinations appear significantly closer than at 2 hours 10 minutes whereas the difference between 2 hours 10 minutes and 2 hours 20 minutes may seem much less significant. What this implies is that it is what may be termed the connectivity between individuals or firms that is important. This reflects the situation that improving accessibility between locations where there are no important economic connections will have less benefit than in situations where these connections are strong. This is about the importance of identifying market areas of activity.

Whilst this may be obvious in concept, and there is evidence from surveys to support it (Burmeister and Colletis-Wahl, 1996), turning this into a robust methodology to appraise investment ex ante is a less clear procedure. Ideally, firm and individual-level data could be used to provide a clearer picture of how firms and individuals use transport and how they will respond to changes. There has been a reluctance to use such survey-based data which attempts to determine behavioural changes in the appraisal of major projects. What has been done in practice is an attempt to model the relationships from an interpolation from more aggregate data. Two recent attempts in the UK are those by KPMG (2013) for the HS2 high-speed rail project and PwC (2013a, b) for the impact of additional airport runway capacity. Both of these have proved to be very controversial, in that they use what is superficially an econometric model, but one that does not meet normal robustness tests.

Moreover, in both cases they imply economic benefits to GDP well in excess of those derived from the conventional extended CBA model with wider economic impacts.

The KPMG model aggregates elasticities for different types of traffic in an unconventional way that has been criticised as econometrically unsound (see, for example, Overman, 2013). The apparent advantage of the approach is that it can produce potential impacts at a relatively fine spatial scale and provides a plausible spatial distribution of gains and losses under two scenarios in which there are assumed to be different degrees of relocation. The problem is that the total economic impact on GDP at £15billion per annum is suggested to be several times that obtained from more conventional methods.

PwC, in their work for the Airports Commission, used a more elaborate spatial computable general equilibrium model. As with the KPMG approach, this is highly dependent on the input assumptions, particularly again the elasticities associated with different types of traffic. Here one of the key issues is the relative treatment of point to point and hub (interlining) passengers and their contributions to the UK economy. This is a fundamental problem with SCGE models that they are highly dependent on the inputs used; in this case from an econometric model that is poorly specified. Again, the model predicts much greater impacts on GDP than conventional modelling and this led to the Department for Transport (2015) recommending using considerably lower figures (£61 billion of net benefits over 60 years against the Airports Commission's £131-147 billion) on the basis that the higher estimates were not sufficiently robust to be the basis of an investment decision. The Department's revised estimates of benefit do not change the recommendation as to whether or where to invest, simply the scale of the benefits. This seems like a further example of a correction to reduce optimism bias (HM Treasury, 2013).

The key point in both of these models is that they represent attempts to go beyond the rather static fixed-trip matrix type approach of even an extended CBA and allow for the redistribution of economic activity following a major transport investment. Unfortunately, in trying to get a tractable model to produce results errors were made and this has thrown doubt on the potential of such approaches. It is clear that such approaches have tended to suggest the potential for larger economic benefits than allowed for by conventional CBA. Does this generate a danger that a fear of overestimating benefits leads to a continuing scaling back of perceived benefits to make them seem less implausible? This seems particularly to be the case with the output from SCGE (spatial computable general equilibrium) models. Whereas CBA of transport projects is typically a partial equilibrium approach focusing purely on the transport sector, SCGE models aim to model the way the entire economy comes back into equilibrium after a shock in one sector (see Bröcker and Mercenier, 2011, for a full discussion of their application in transport). Such models are now used widely, but are still seen as unfamiliar in that they have an essential black-box quality. Applications continue to rely heavily on data (especially elasticities) imported from outside the project in question, and these are usually derived from evidence on marginal changes that may be less appropriate for use in major projects.

Perhaps the main problem is that approaches such as SCGE models appear to present such an apparently accurate estimate of benefits. In most cases they can be used to present a range of benefits with a certain degree of confidence and any value in that range suggests a

positive net present value for a project. But project promoters typically like to identify a single value rather than a range and a high value is normally preferred. High values attract attention, but also attract opposition. Here the politics of appraisal takes over from the technical evaluation issues; how do we provide an objective appraisal of a project independently of the political forces in favour or in opposition to the project? This is where complex models present a problem as a complex model such as an SCGE model presented by a project promoter is difficult to challenge by an objector who may not have access to equivalent technology and/or may not have the technical expertise available to assess the output of the model. Getting the balance right between complexity and accessibility may prove to be more important than improving accuracy through more sophisticated modelling.

But this will require policy-makers being prepared to accept that forecast returns are estimates within ranges and can never be made totally precise and accurate by just a bit more modelling. If a range of different approaches give similar results within an acceptable range, then the cost of delaying a project to get a slightly more accurate result may be greater than any variation in benefits. Essentially this is suggesting that policy-makers should be slightly less risk averse to variations in forecast returns on a project when there is clear evidence of a positive net present value. The calculation of that present value does, however, depend on having a clear objective in terms of the expected benefit from a project. If a project is designed simply to improve conditions for existing travellers, then a simple cost-benefit focussed on user costs and benefits is appropriate and this is likely to be as accurate as the demand forecasts allow. Where a project, as is increasingly argued to be the case, is expected to produce a significant wider economic impact, often referred to as transformational, then a more nuanced approach is required. Laird et al (2014) have shown the limitations of conventional cost-benefit analysis for projects making such a claim, but do not present a clear blueprint for dealing with such projects. Vickerman (2017) addresses the question in terms of the claims made for high-speed rail projects and presents some evidence in terms of the structural changes in the economy following the introduction of high-speed rail services (see also Chen and Vickerman, 2017). Even though there is some support for the view that transport does contribute to some structural change, distinguishing the direct effects of a transport intervention from other factors in an ex post evaluation presents serious problems.

Some examples

To illustrate the argument made above we take some evidence from recent and current projects in the UK (see Vickerman, 2015, 2016, for more detail). Since the application of the newer methods for estimating wider economic impacts is relatively recent and two of these projects are not yet complete it is difficult to assess the accuracy of these methods. We compare here one completed project, the HS1 high-speed rail line between London and the Channel Tunnel in the UK, for which regeneration benefits were claimed but not formally estimated, with two where various methods for estimating wider impacts were included in the appraisal. The first, Crossrail, was the first project where a formal estimate of agglomeration benefits was included; the second, the HS high-speed rail network between London and the Midlands and North of England has been the subject of more novel and controversial attempts to capture economic impacts.

HS1, the high-speed rail line between London and the Channel Tunnel, was justified on the basis of the regeneration impacts it would have by taking a route that went via North Kent and East London. Both of these were less prosperous areas of South-east England. The regeneration prospects were largely based on the perception that improving transport connections in areas where accessibility was generally poor would be beneficial. The regeneration benefits were essentially aspirational rather than quantified as part of the appraisal. The line opened in 2007 for international traffic between London, Paris and Brussels with a new stop at Ebbsfleet (in the Borough of Dartford in North Kent) for some trains, but the station at Stratford in East London is not served by these trains. In 2009 regional services were introduced serving a wide range of towns in East and North Kent that use the high-speed line for part of the journey. Speed improvements meant that the typical time from Ashford to London was reduced from 80 minutes to 37 minutes. The project has been criticised for neither delivering the expected number of passengers nor the regeneration benefits (Atkins et al, 2015). Passenger growth has been less on international trains although the domestic regional services have out-performed the rest of the UK rail network in terms of growth. Atkins et al (2015) suggest that although regeneration benefits have been slow to appear, and the line did become operational at the height of the 2008 financial crisis that delayed some expected developments around stations, especially at Ebbsfleet, the time lag that might be expected for such changes could be longer than the five years or so evidence.

A more focused analysis of structural change (Vickerman, 2017; Chen and Vickerman, 2017) suggests that growth in GVA in the districts of Ashford and Dartford outperformed the regional average during the period up to and after the inauguration of the line. Looking at structural change, employment in knowledge-related industries also grew faster, especially in Dartford. But the picture is not simple; there is some evidence of anticipation that has been less achieved in reality, there is evidence of other factors such as the accompanying land-use planning effects found important in French studies (Crozet, 2013), and there is evidence that those locations with existing advantages have continued to perform well even if less benefited by the introduction of high-speed rail. On the other hand, the closure of a major pharmaceutical plant in East Kent and the impact of the 2008 financial crisis dampened the potential economic impact of improved accessibility on employment.

The regeneration benefits were seen as essentially aspirational in the case of HS1, they were decisive, less in choosing to go ahead with the project than in choosing its final route. The bigger problem was in financing a project, made very expensive by the amount of tunnelling required to counter environmental opposition, against the background of international traffic failing to meet forecast expectations.

Crossrail is a new cross-London rail line linking routes to the west and east of the city through a new tunnel serving various locations in central London. Due principally to the tunnelling involved this is an expensive project estimated at around £16 billion that is due to open in 2018. The direct user benefits were only estimated to be of the order of £12bilion based on a conventional CBA and the decision to proceed depended on the estimation of wider economic benefits based on the work of Graham (2007). This raised the estimated total benefits to around £19-20 billion from belter sorting in the labour market leading to tax gains and estimates of much larger elasticities of productivity with respect to

agglomeration in the sectors concentrated in central London, namely financial and business services, than traditionally found in studies of the benefits of city size (Glaeser and Gottlieb, 2009). In Graham's study these were estimated at around 0.22 to 0.24 against those for manufacturing, the traditional basis of agglomeration economies in cities, of 0.07 to 0.08, lifting the estimate for the whole economy to 0.12. It remains to be seen how far both the projected ridership and the estimated benefits can be realised. Given that the analysis was completed in 2005 before both the financial crisis of 2008 and the decision in 2016 for the UK to leave the EU it is clear that it will be extremely difficult to make an easy comparison.

HS2 is the project to build a major high-speed rail network linking the major cities of the UK with new lines initially between London and Birmingham and then extending to Manchester, Derby-Nottingham, Sheffield and Leeds with trains being able to run off the new network to serve other major cities in northern England and Scotland. In this case the primary objective of the scheme, like the first new lines in Japan and France, was largely one of expanding capacity to meet the forecast demand for rail traffic by 2030 and beyond. Demand forecasts were thus again critical, although user benefits depended heavily on the value of business time savings; these account for 70 per cent of net user benefits. In the case of HS2, the Benefit-Cost Ratio, on the basis of just direct user benefits is around 1.4 for Phase One and 1.8 for the full network (HS2, 2013). Wider economic impacts measured by the standard Department for transport methodology following the example of Crossrail only add a further 18 per cent to Phase One benefits and 23 per cent to the full network benefits, raising the BCR to 1.7 and 2.3 respectively.

Partly because of the criticism of the value of business time savings benefits and fears of cost overruns on a project of this scale, attention switched to the value of the wider impacts. The standard methodology was felt to underestimate the full economic impacts of a project costing more than £50 billion and this led to the increasing emphasis on the transformational nature of the project rather than just a tool for reducing travel time and increasing reliability through increased capacity. The political desire to push the project ahead on this basis required a methodology that could provide some evidence in support. The work by KPMG (2013) discussed earlier provided the basis for arguing that the project could raise UK GDP by as much as £15 billion a year compared with a net present value of benefits of £71 billion over 60 years from the standard CBA with wider economic impacts included. Moreover, the KPMG work looked at the regional impacts suggesting that, depending on assumptions made about the extent to which businesses relocated to take advantage of greater connectivity, these went largely to regions outside London, countering the centralisation arguments put forward by many opponents of the project. For the full network it was estimated that London would only receive a £2.5 billion per year gain, less than it would just from Phase One linking London to Birmingham, whilst the West Midlands would gain £3.1 billion once it had better connectivity both south and north. The precise value of these estimated gains is obviously open to dispute and depends on key assumptions, but it does suggest that even if these estimates were halved there would still be considerable gains over and above those estimated by the current standard methodology.

It is perhaps too early to be able to draw any firm conclusion from these studies. HS1 has only been in service for 10 years, and the domestic services for only 8 years. Crossrail will

open in 2018 and the first stage of HS2 is scheduled to be in service only in 2026. The studies of Crossrail and HS2 show a continuing search for an understanding of the longer term structural changes brought about by major infrastructure that even extended CBA analysis with an allowance for wider economic impacts from labour market sorting and agglomeration is not able to capture. But the experience with HS1, and the comparisons between Europe and the Pearl River delta in Cheng et al (2015) and between Kent and the Yangtze River delta in Chen and Vickerman (2017) do suggest that such structural changes can be observed. This is both in terms of centre-periphery type convergence and divergence changes and more specifically in the response of knowledge-based industries. That the ex ante methods used in the cases of HS2 and the impacts of runaway capacity have not yet been able to capture this convincingly suggest that there is still scope for further development of more robust models.

Concluding thoughts

We have focused here on the problems concerning major investments, the ones most likely to have impacts above and beyond those treated in conventional CBA. This is not necessarily about size measured by the cost of an investment; sometimes smaller investments can be powerful in unlocking new opportunities, but these are harder to identify ex ante. Major investments with potentially transformational economic consequences typically involve longer distance transport and take longer to realise. Forecasting long-distance trip making over long periods is problematic and requires assumptions to be made about economic growth and about both business and non-business travel behaviour. Even within the constraints of a conventional standard or extended CBA there are problems concerning the values of in-vehicle time savings and in particular whether business travel-time savings are conventionally over-valued in relation to the potential for productivity enhancement in a modern age. Although the tendency to overplay the potential for in-vehicle work with modern communications needs to be resisted, more work is needed in this area. Perhaps more significant and highlighted in reactions to recent alternative methods of evaluating the wider benefits are the assumptions made on fare structures and price elasticities. This is particularly in relation to the use of marginal elasticities where step-changes in time and prices are envisaged, but it also requires careful handling of the aggregation of such elasticities across modes and different types of user.

It is not yet clear that we have solved the issues relating to the correct means of appraising wider economic impacts. Whilst reasonably robust results can be obtained from applications in metropolitan areas where the effect on the economic mass from the increasing effective density or thickening of local labour markets is clear. It is less clear how the agglomeration effect works an inter-urban context. Connecting cities will have differential effects on each city's labour market as well as on the aggregate labour market of both cities. Most interesting is how the process of specialisation works; does it relate to sectoral shifts or is it a subtler process at the level of specific skills or occupations. This is often more about the internalisation of the impacts within firms rather than between firms as they seek to balance scale economies against lower transport costs.

There is a danger in this that there is a trend towards over-analysis that leads to paralysis in decision making over new investments. The desire for policy-makers to get everything right to avoid criticism leads to delay. And whilst there is clear evidence of optimism bias in most

new projects, sometimes risks have to be taken. The usual observation is that we need more ex post analysis of projects, but this often fails to recognise that large-scale projects are almost by definition unique and without understanding fully the factors that lead to success in one project and failure in another little will be learned from this exercise.

How much risk should be left in any appraisal? Much of the investment for growth argument in transport projects depends on a balance between hard evidence and perception. Often perception gets in the way of the hard evidence leading to claims about economic transformation and job creation that are hard to justify. The claim that major transport investment can rebalance the economy is often justified by the observation that the economy is unlikely to be able to be rebalanced without investment in transport. But that does not imply direct causality from the investment to the rebalancing; transport is an enabling factor, often an essential enabling factor, but not necessarily the core cause of the change.

This leaves us with some outstanding issues. First, is the relationship between conventional measures of accessibility and the less precise notion of connectivity, used for example in the KPMG study of HS2; this requires further work to understand whether the latter is a better measure of changes in spatial potential. Secondly, there is the question of the impact on cities versus their wider city regions; is the rebalancing of secondary cities in a network more at the expense of their respective hinterlands than of the core city. Thirdly, the appraisal of major investments is often undertaken in isolation of other improvements in transport; how, for example, do we compare improvements in a local/regional network with major national investments? Improving the former may be more beneficial than investing in the latter, but methods for aggregating the impacts of a series of more local investments are less well advanced than those for appraising major stand-alone projects.

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