International Transport Forum

Incorporating Wider Economic Impacts within Cost-Benefit Appraisal

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Anthony J. Venables
Department of Economics
University of Oxford
UK

OECD

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Anthony J. Venables

Department of Economics

University of Oxford

UK

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International Transport Forum
2 rue André Pascal
F-75775 Paris Cedex 16
contact@itf-oecd.org
www.itf-oecd.org

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This paper analyses three main mechanisms through which transport improvements have impacts that deliver real income gain over and above user-benefits. One is economic density and productivity, a second is induced private investment and associated land-use change, and a third is employment effects. There are relatively well-established methodologies for incorporating the first and third of these in cost-benefit appraisal, and these methodologies are reviewed in the paper. For the second, the paper outlines how transport induced investments can create consumer surplus, and describes a method for quantifying this in cost-benefit appraisal. Data issues encountered in implementing these methods are discussed.

Introduction

The case for investment in transport improvements is frequently made in terms of impact on economic performance. There is an expectation that they will act as a catalyst for private sector investment, creating jobs, boosting economic activity and growing (or rebalancing) the local (or national) economy. These 'wider economic impacts' typically go beyond a conventional transport cost-benefit appraisal (CBA) which focuses on the user-benefits created by a project, often derived under the assumption of no change in land-use. This is an unsatisfactory situation which creates a disjoint between the strategic arguments put forward in support of a project, and the associated economic analysis and CBA. Even if the value of wider economic impacts turns out to be small, appraisal must engage with the arguments put forward by scheme promoters and local interests or otherwise risk marginalisation, resulting in a policy process in which decisions are based on bad economics.

Incorporating wider economic impacts in CBA is challenging and has its own risks. Broadening the set of mechanisms that are studied creates the risk that bad arguments may appear to be legitimised, and that effects can be exaggerated. Studies tend to concentrate on areas where a transport improvement expands economic activity, and to ignore areas from which this activity may have been displaced. This, together with reporting of GVA effects, makes it possible that fundamental economic principles – above all that drawing resources into an activity has an opportunity cost – can be overlooked. The challenge is to be ambitious in broadening the scope of appraisal while remaining grounded in rigorous analysis of the social value of transport investments and of any private sector responses that they induce.

How should this be done? One answer is a full economic modelling exercise, in which resource constraints are properly imposed, private sector responses are modelled, market imperfections are made explicit, and real income (utility) benefits accurately calculated. This may be appropriate for some large projects, but is not a general solution. Such models are expensive and it would be disproportionate to use them for the majority of projects. A consequence of their expense is that typically one model is built and then applied to different situations in a somewhat mechanical manner, paying insufficient attention to the characteristics of the scheme and its likely effects. They then fail to capture impacts, which are likely to be quite different for an urban commuting scheme, an urban by-pass, or an inter-city rail line. These projects have different stated objectives and will trigger different private sector responses. It follows that the appraisals must be designed to be context specific. Some should focus on the consequences of getting more people into a city centre, others on better linking remote locations, and so on.

The need, therefore, is to develop a framework of possible channels or mechanisms through which wider economic impacts can occur, and to find the evidence needed to quantify these mechanisms and apply them in appraisal. The application of these mechanisms to particular projects needs to be context specific, informed by the strategic narrative that motivates the project; some mechanisms are applicable to some types of transport projects, others to others. For larger projects the mechanisms can be formulated in a complete economic model. For other projects this has to be done by the analyst's linear approximation to the formal model. This means that component parts will be studied separately and then added up. Of course, the relationship between the components must be consistent (so adding up does not double-count), the components must be exhaustive (so if some activity expands others may contract), and the focus should be on identifying the true social value of effects.

This paper sets out and discusses the key components of this approach. The next section gives the outline and relationship between components, which are then discussed more fully in the remainder of the paper. Some of the elements are now well established, and are applied in practise, for example in the UK Department for Transport's appraisal guidance.[1] Others are more challenging and need to be the subject of further research.

The effects of a transport improvement

A transport improvement brings time and cost savings to users of the transport network.[2] The users are individuals and households in their work and leisure activity, and firms which need to move goods, services, and employees. Time and cost savings change traffic flows, leading to increased flows in some parts of the network and possibly less traffic elsewhere. These changes in costs and in flows are the subject of sophisticated modelling efforts and are the core of transport appraisal. They are illustrated in the left hand column of Figure 1. We follow practise in the transport literature and refer to the social value of these change as the *user-benefits* of a project.[3] While they constitute the centre of any transport appraisal, they are not the focus of this paper.

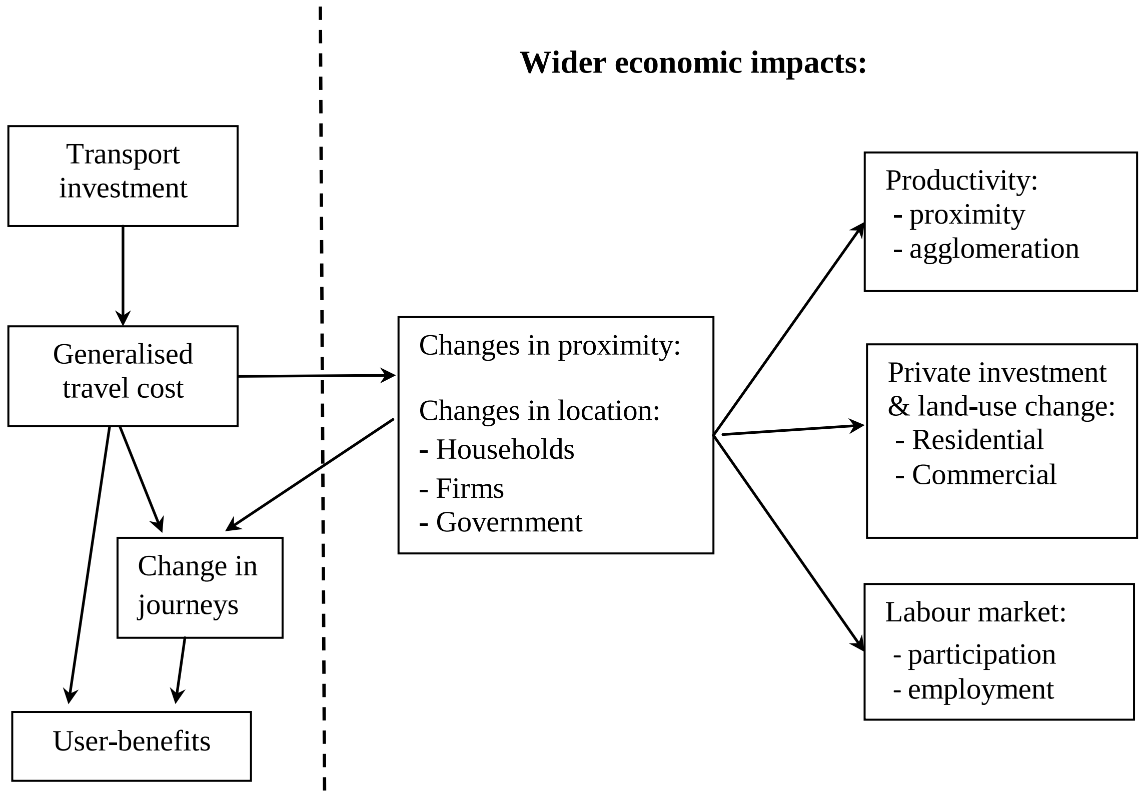
Wider economic impacts are illustrated in the right hand part of Figure 1, and arise as a consequence of transport's impact on economic geography. Better transport increases proximity, making economic agents closer together, and may also trigger relocation of economic activity as firms and households respond to new opportunities. Together, these changes create potential sources of 'wider economic benefit' through three main mechanisms.

The first is that proximity and relocation shape the effective density of economic activity, and thereby productivity. This is over and above the direct productivity effects of faster journeys, and arises because of the intense economic interaction that occurs in economically large and dense places. This is why cities and other agglomerations exist. This observation is backed-up by a substantial research literature that quantifies the positive relationship between economic density and productivity.

Second, a transport improvement, other things equal, will make affected locations more attractive destinations for investment. User benefits are experienced by residents, workers, and firms, and this may induce investment to occur, changing land use. Investments include residential development of land, the development of office centres or retail parks, or the redevelopment and regeneration of city centres. They may in turn generate agglomeration and productivity effects, and also have further value by changing the 'attractiveness' of affected places.

Third, there may be impacts in the labour market, on the both the supply and demand side. On the supply side, transport may enable labour force participation. On the demand side, jobs will be created in some places and some activities, and possibly lost in others.

Figure 1. **The effects of a transport improvement**



To include these impacts in transport appraisal three questions must be addressed. First, is there a sound reason to think that they create a *social value*, over and above user-benefits? This requires understanding the mechanisms at work and, essentially, identifying a market failure. Absent such failures, (small) quantity changes are of zero social value, as the price system equates the marginal value of changing an activity to its marginal cost. But if transport induces a change that interacts in some way with a market failure then it will create additional benefit (or cost). Notice that these valuations are in terms of social welfare (ultimate household benefit), not of GVA. The distinction between the two is well known, and the focus throughout this paper is social welfare.

Second, local changes have to be set in the context of the national aggregate. In practise, this means thinking hard about *displacement*. For example, job creation in one region may be at the expense of job losses in another. Each change may be of interest to local stakeholders, and it may therefore be appropriate to report them in project appraisal. However, national appraisal has to report national aggregates and provide the complete view which may be missing from concentration on effects in the neighbourhood of the project.

Third, the feasibility of *predicting and quantifying effects* has to be considered. This is technically challenging, particularly for large projects which are claimed to have transformative effects. The difficulty is compounded by complementarities between transport projects and other actions, including other policy changes. A single transport project is unlikely to be sufficient to unlock transformative change, its value depending on complementary transport improvements, land-use planning changes, and perhaps even wider demographic changes. Addressing this requires multiple scenarios, rather than the presentation of a single benefit-cost ratio (BCR).

The next three sections of this paper look, in turn, at the impact of transport improvements on productivity and proximity, induced private investment and land-use change, and labour market effects. The emphasis will be on mechanisms through which transport may create wider benefits – i.e. the way in which the economic impacts interact with market failures to create sources of additional gain. The penultimate section addresses the issue of how, in practice, it might be possible for appraisal to make quantified estimates of effects, particularly at a national level, and including displacement effects.

Proximity and productivity

It is widely recognised that economic density – the clustering of activity in towns and cities – has a positive impact on productivity, and that such clustering is dependent on effective transport systems. Some of the productivity effects come from interactions between different economic agents that are not fully internalised, creating market failure and wider economic benefits, as recognised in the appraisal methodology of the UK Department for Transport.

Mechanisms

Transport improvements enable savings in transport and communication costs for firms, workers, and consumers, enhancing effective proximity. In turn, cheaper, more reliable and faster transport may allow firms to change the way in which they organise their logistics or production (e.g. just-in-time manufacturing technologies). These gains are user-benefits, and are accounted for in calculation of those benefits. They should not be double-counted as a wider economic impact.

Wider economic impacts arise when economic agents cannot capture the entire benefits (or costs) of their actions, i.e. they create externalities that are of value for other agents.[4] These may be technological (such as knowledge spillovers, which are not intermediated through a market) or pecuniary (going through an imperfect market). By supporting thicker markets and more intense economic interaction, proximity creates a number of these effects. Probably the most important mechanism is that scale and density together create an environment where firms and workers can develop highly specialised products, services and skills. These are typically inputs to firms – the specialist components, and engineers, lawyers, finance experts who may be necessary to efficient operation of a firm.[5] A new specialist supplier will set up once the market is big enough, and the presence of the new supplier will make the cluster more attractive as a location for other firms that use the product or service. This grows the market for specialist suppliers, encouraging further entry and hence a cumulative causation process. This is the classic process of cluster formation, such as an auto-industry cluster of assemblers and suppliers or a film industry cluster of directors, actors and technicians. There are spillover effects (externalities) in this process. Indivisibilities or increasing returns to scale mean that a service, skill, facility or product will only be supplied if the market is big enough. The supplier is generally unable to capture all of the benefit, so there is a positive net effect created for others in the cluster.

A further mechanism arises as competition is likely to be intense in a large and dense cluster so monopolistic pockets of inefficiency are less likely to survive. Monopsonistic behaviour, occurring where there are few potential purchasers for a product or skill, can deter investment; this too is less likely to be a problem in a large and dense cluster. There may also be direct knowledge spillovers, as 'mysteries of the trade become no mysteries; but are as it were in the air' (Marshall 1890).

The mechanisms may operate within particular sectors or across a wide range of sectors, the former being referred to as localisation (or Marshallian) economies, and the latter as urbanisation (or Jacob) economies. Within-sector productivity effects create a force for sectorally specialised clusters and possibly specialised cities. This varies across sectors; it is important in some manufacturing sectors; developed country manufacturing exhibits automotive clusters, and developing country manufacturing contains clusters in labour intensive sectors such as textiles and garments. Clustering is particularly prevalent in business services such as finance, law, and media. Both the creation and diffusion of knowledge work particularly well in clusters, and a large body of literature points to the spatial concentration of innovative activities.[6]

Valuation

A reduced form approach to measure these effects has two elements, one to construct a measure of effective density or 'access to economic mass' for each place, and the second to link productivity to this measure. The first stage, measurement of access to economic mass, typically takes the form $ATEM_i = \Sigma_j f(d_{ij})Emp_j$**.** This says that location i's access to economic mass, $ATEM_i$, is the sum of employment in all districts (indexed j), weighted by some decreasing function, f, of their economic distance to i, d_{ij}. Thus, if a place is near to lots of other places with high employment it will have high *ATEM*. The second step links a location's access to economic mass to its productivity through the relationship, $Productivity_i = F(ATEM_i)$.

A substantial econometric literature quantifies these relationships, seeking to find functions F and f by estimating equations of the form

$$Productivity_i = F(\Sigma_j f(d_{ij})Emp_j). \qquad (1)$$

Appendix I reviews key studies, and here we simply note the following. The relationships can be investigated at a sectoral level (localisation economies) or an aggregate level (urbanisation economies). Economic 'distance' can be measured in different ways (distance, travel time, or generalised travel cost), and economic activity represented by employment or by other activity measures. The unit of observation can be spatial aggregates (e.g. location/ sector averages) or can be individual firms or workers. Estimation includes controls for other determinants of productivity; for example, if the unit of observation is a worker, then skills and age will be amongst the controls.

A reasonable consensus has emerged on the magnitude of effects. An authoritative (although quite old) survey of the literature finds that 'in sum, doubling city size seems to increase productivity by an amount that ranges from roughly 3-8%' (Rosenthal and Strange 2004, p2133). This means that the elasticity of productivity with respect to city size is in the range 0.05- 0.11.[7] This is a large effect in the cross-section, suggesting that productivity in a city of 5 million is between 12% and 26% higher than in a city of ½ million. A meta-study (Melo et al. 2009) suggested that the mean estimate of this elasticity across several hundred studies is somewhat lower, at 0.03, although pointed to considerable variation according to sector, country, and technique employed by researchers. Recent work using individual data (and controlling for individual effects) produces estimates of similar magnitude. At the sectoral level, there is evidence of heterogeneity, with business services and high technology sectors exhibiting the largest localisation economies.

A critical issue for transport appraisal is the construction of the measure of access to economic mass $ATEM_i = \Sigma_j f(d_{ij})Emp_j$. ‘Distance’, d_{ij}, is typically measured as a composite of generalised travel costs (GTC) of different modes of transport. The composite can be constructed either by assuming weights of different modes in some functional form (e.g. an index using modal shares as weights) or by letting econometrics determine the contribution to productivity of access by different modes. The latter is preferable, but hard to identify precisely as the GTC of different modes are highly correlated across origins and destinations. The spatial scale of effects (captured in the function f) is generally found to be quite limited, with effects concentrated within travel to work areas (e.g. driving times of up to 45 minutes), and attenuating quite rapidly thereafter.

The effect of a transport improvement

A transport investment can change access to economic mass in two distinct ways. One is that it changes levels of activity in each place, Emp_j. This is sometimes referred to as ‘dynamic clustering’ and is associated with land-use change; we discuss it further in following sections of the paper. The other is a direct proximity effect. Transport changes the matrix of economic distances (GTC) between places, d_{ij}, making places better connected and increasing the effective density of economic activity. This is sometimes referred to as ‘static clustering’. Implementing this source of wider impact does not require estimates of induced investment response or land-use change. A transport appraisal will have estimates of how the project will change the matrix of GTC between places. This can be fed into equation (1) and the ensuing productivity changes for each location can be computed. A productivity increase derived this way is an additional source of welfare gain – a wider benefit, on top of user-benefits.

Investment and changes in land-use

A transport improvement will generally change the pattern of private investment across locations, and this process of encouraging – or even 'unlocking' – private development is often put forward as one of the major impacts of transport projects. The investment response is driven by the user-benefits experienced by residents, workers, and firms. This response changes traffic flows, changes which should be included in calculation of user-benefits (Figure 1). Are there circumstances in which the induced investment creates wider benefits, additional to the user-benefits? We address this in two different contexts, first looking at residential development that is dependent on transport improvement, and then at relatively large scale commercial developments – such as city centre redevelopment – for which transport improvement is the catalyst.

Dependent residential development

Transport is a necessary part of many new residential developments, sometimes at a large scale. The proposed 'Crossrail 2' in London is linked to construction of 200 000 new homes in North London. What are the circumstances under which this leads to benefit over and above those accounted for in user-benefits? The economic principles for valuing any such change in land-use are straightforward, but worth restating.

Suppose that initially the number of houses in a particular area is Q_0, and the area has a transport improvement which gives the residents of each house user-benefit ΔT. In the new situation – after the transport improvement and any other policy changes are made – the number of houses increases to Q_1. Using standard demand and supply analysis (Appendix II), the change in welfare consists of two parts. The first is user benefits to existing and new residents, approximated by the rule of a half, i.e. $UB = \Delta T\{Q_0 + (Q_1 - Q_0)/2\}$. The second captures any inefficiencies in land use, as measured by the wedge between price and marginal cost (where marginal cost is the value of the land in its alternative use plus house construction costs and any further costs, such as induced congestion externalities). Calling this wedge in the initial and final situations PC_0, PC_1, the extra social value derived is the number of new houses built times the average value of the wedge, $WB = (Q_1 - Q_0)(PC_0 + PC_1)/2$.

The wider-benefit, WB, part is proportional to the average gap between marginal social benefits and marginal social costs. What supports such a gap? One possibility is planning restrictions, although only if they are more restrictive than is efficient. Thus, the planning authority may place a high value on congestion costs or other negative externalities created by the development, this narrowing the gap between marginal benefits and costs. Another possibility is that there is monopoly power in the supply of housing. Developers holding large stocks of land will restrict supply (equating marginal cost with marginal revenue, not price), and thereby creating such a gap. It is possible that this monopoly power is not exercised by developers, but by existing residents who have captured the planning process and are seeking to restrict building in order to maintain high property prices.

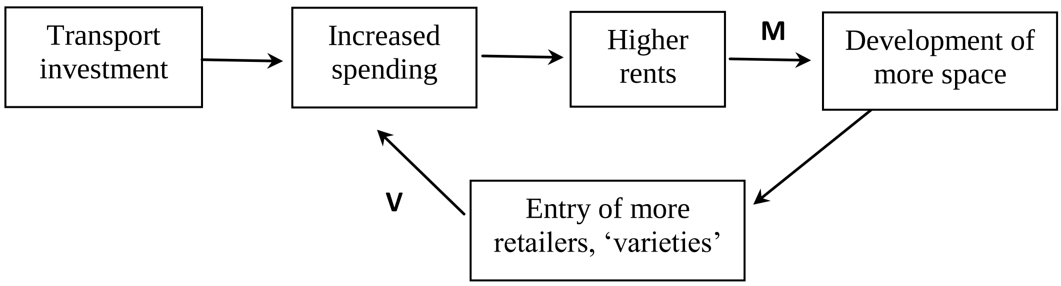
It is sometimes claimed that the full gain (UB + WB) is given by the land-value uplift. This is true only if two conditions hold. First, that the increase in supply of housing does not reduce price (see Appendix II). This requires that the price elasticity of demand is infinite (or the extra supply extremely small). Otherwise, if the elasticity is finite (the demand curve is downward sloping), then price is reduced so not all the benefit goes to land owners, some accruing to house occupants.[8] Land value uplift then underestimates the welfare gain. The second condition is that all externalities (such as increased congestion) are fully accounted for and charged in the calculation of costs. If not, then the presence of uncharged negative externalities will mean that land value uplift over-estimates the benefit of development.

Commercial land-use change

A more complex situation arises if transport acts as the catalyst that induces private investment in a large commercial development – retail, office, and perhaps involving redevelopment of a substantial parcel of city land. It is often suggested that such developments create an additional benefit by making an area 'more attractive'. [9] Under what circumstances do these benefits exceed the user-benefits received by travel to and from the area?

A conceptualisation of this is offered in Figure 2; the context developed in the figure is that of a retail development, although the arguments put forward are more general.[10] A transport improvement increases spending in a place, as visits respond to lower travel costs. Increased spending raises profitability of shops and hence the landlord is able to charge higher rents. This makes it profitable to develop more space, redeveloping the site – by extension, or perhaps by building taller. This expansion creates more floor space and hence the entry of more shops, in turn making the place a more attractive destination and creating the feedback loop illustrated in the figure.

Figure 2. **Commercial development**



User-benefits trigger this process, and wider-benefits arise if there are interactions with market failure. There are, arguably, two sources of market failure in this process, labelled M and V on Figure 2. The first, M, arises as there may be barriers preventing the level of development reaching an efficient level and hence creating gaps between marginal benefits and costs. The second is at point V, and captures the idea that places become more attractive as they attract more stores. We look first at the attractiveness argument, V, and then turn to barriers to development, M.

The attractiveness argument has foundation if entry of new stores creates some consumer surplus, i.e. consumer utility over and above the value of their spending. This will arise if stores are differentiated from each other, and is formalised in many sub-fields of economics as a variety effect. For example, in international trade it is argued that much of gains from trade (at least, intra-industry trade between similar countries) arises from countries being able to access a wider range of products (for quantification of these effects see Broda and Weinstein 2006). By analogy, introducing new stores in a retail development creates consumer surplus since it increases the range of choice (number of varieties) available to consumers. The standard methodology for quantifying the gain assumes that demand for the products under study is iso-elastic. Denoting this elasticity σ, the ratio of consumer surplus to expenditure on a new variety is $1/(\sigma - 1)$ (Appendix II). Hence, the value of any variety effect, UV, is

UV = change in expenditure/(σ – 1). If products are perfect substitutes – the retail development just means more identical stores – then σ is infinite, there is no increase in 'attractiveness' and UV = 0. [11] Typical estimates of σ from other contexts suggest values in the range 6 – 10, suggesting a wider benefit mark up of 10-20% of expenditure in the development.

Three further remarks need to be made about the variety effect. First, following the approach above, it is grounded as a mark-up factor on the change in consumer expenditure in the development. This is project specific data that is observable *ex post* and likely to be part of development plans at the appraisal or planning stage. Thus, estimates of possible wider-benefit created can be tested against the commercial proposition put forward by developers. This avoids having to resort to ad hoc shifts in demand curves in order to capture these effects.

Second, the discussion has been in terms of retail development. An exactly analogous argument applies to an office development scheme, but with the variety effect restated as an agglomeration effect. In both cases entry of a new firm (shop or office) creates a positive spillover, as the entrant is unable to capture the entire benefit created. This analysis is therefore a restatement of the agglomeration and productivity arguments of the previous section. Of course, only one of the two approaches should be followed for any particular project.

Third, these arguments (and those of the preceding section) have to be placed in the context of product market displacement effects. Would the activity – manufacturing, commercial or residential – take place somewhere else, absent the transport improvement? If so, is it subject to the same market failures? Effects across all geographical areas then have to be combined – some of them positive, and others negative. We return to this issue in the penultimate section below.

We now turn to the other possible source of market failure, the presence of barriers to development, M. Many of the points follow the earlier discussion of residential development. Thus, there may be monopoly power as a developer perceives that building extra space reduces rents. The planning system may over-restrict development, particularly if it is looking only at the interests of local residents in the development of a scheme that could bring benefits to a more spatially dispersed group of shoppers of workers. As with residential development, an increase in quantity supplied brings wider benefit proportional to the gap between marginal social benefit and cost.

Additional barriers may be present in large scale commercial developments as they involve investments by many distinct decision takers – property developers and retailers in the conceptualisation of Figure 2, or perhaps multiple developers in a large scheme. If the profitability of the project for one decision taker depends on investment by others (as illustrated by the feedback mechanism of Figure 2), then there is potential for coordination failure. It is not in the interest of any single investor to invest, but each would invest if they knew that others were. This positive interdependence of profitability could arise in starting a new cluster of economic activity (i.e. the productivity arguments of the previous section) or in launching new retail or urban redevelopment schemes. Coordination failures thus lead to low level traps and require some policy mechanism to coordinate individual actions and break out of the trap. Transport investment can be such a mechanism.

A simple example of this argument is a growing city in which it is clear to all that a secondary centre somewhere on the edge of the city will be successful, but there is no agreement as to exactly where. The expected return to a private investment in any particular place is therefore low or negative, since this may not turn out to be the place that takes-off. This uncertainty creates the low level trap – no-one invests anywhere. There are different ways to resolve this problem. A sufficiently large private developer could move first, being relatively confident of being followed by other investors. The city authorities can produce an urban plan, selecting areas for development. Or transport infrastructure can be built. This now has a dual function; it delivers access and user-benefits and also is a credible signal that a particular place will develop. If this resolves the coordination failure then the return to the investment can, potentially, be many times greater than the user-benefits alone.

A different example of coordination failure is regeneration of a dilapidated area of a city. It is not worthwhile for one property owner to improve, given other properties remain run-down. But if all do, all are better off. The role of transport as a catalyst to break this trap is less clear-cut than in the previous example (uncertainty is not about where, but about the likelihood of action). However, by increasing the value of properties in the area a transport project may also increase the return to property improvement; if some improvements are initiated it may cascade, raising returns to others.

Evidently, assessment of these effects is context specific and subject to a great deal of uncertainty. Studies of the role of transport in these contexts (e.g. in regeneration schemes) frequently suggest that transport is an important part of a package of measures, but is unlikely to be transformative by itself. More generally, there is considerable inter-dependency between transport and other public projects and policies. Synergies extend not just across transport projects and associated private development, but also across government policies, including land-use policy and wider urban and regional development measures. Transport appraisal needs to recognise potential synergies arising from interaction between policies. If each element of a policy package is necessary for change, and no one of them independently sufficient, then the scheme has to be evaluated as a whole. Scenarios can be produced of the effects of different combinations of policy and other changes, and each scenario can be valued. However, it is not generally meaningful to attribute returns to each separate part of an integrated policy package.

Employment impacts

Job creation is often held up as a major impact of transport investment, with two distinct mechanisms being suggested. One is on the supply side: better transport may make it easier for people to get to work, and may reduce discouraged worker effects. The other is on the demand side, with induced investment creating new employment opportunities. We discuss each in turn noting that, as usual, the benchmark is a situation where a change in quantities – of jobs or other variables – is of zero social value.

Labour supply: participation and tax wedges

On the supply side, individuals' labour force participation decisions are based on comparing the costs of working (including commuting costs), against the wages earned from a job. By reducing the cost (in time and money) of getting to work, a transport investment is likely to increase the returns to working; some people, for whom the net returns to entering the labour market were initially not worthwhile, may decide to enter. Such an increase in labour supply and employment raises GVA but, in the simplest circumstances, does not increase welfare. Initially, the individual was not working because the utility from leisure exceeded that from working, net of commuting costs. If a transport improvement triggers work, the benefit to the individual cannot be greater than the user-benefit received (if it were, the individual would have chosen to work in the first place). However, this conclusion changes if there is an income tax wedge (or loss of state benefits). The individual does not receive the full value of work undertaken because a fraction of it accrues to government. The full gain from entering employment is then the user-benefit plus tax revenue paid (or benefits not received).

This is operationalised in the UK's transport appraisal by calculating the change in the generalised cost of commuting; then estimating how this increased return to working affects the amount of labour supplied (via an elasticity of labour supply with respect to earnings), and hence calculating how much more income is generated and how much of this accrues as income tax (or benefits not paid). By the argument above, only the tax raised (or benefit saved) by the additional employment and output is included as an additional benefit from the scheme.

Similar principles apply if transport triggers a move to more productive jobs. For example, suppose that there is a low paid job nearby and higher paid jobs further away. A reduction in the cost of travel might cause individuals to switch to the higher paid jobs. However, their calculation of the net private gain from switching jobs is based on post-tax income, not the pre-tax wage. The exchequer captures the tax wedge in this decision. This is exactly analogous to the participation decision discussed above, and was part of the Crossrail appraisal (see Box 1 in the next section).

Labour demand and unemployment

Turning to the demand side, if new jobs are created in one place, then the value of output produced by each new job is the wage, and this is set against the value of what workers would have done, absent the new jobs. For workers drawn out of involuntary unemployment the alternative is of low value, so the net benefit is large. This may be an important effect in developing economies or in regions with significant structural un- (or under-) employment. However, for long-run transport projects in reasonably well functioning market economies it seems likely that the labour market will adjust to some 'natural rate' of unemployment which is independent of transport investment. If this is the case then an increase in labour demand is met either by increased labour force participation or by drawing workers out of other employment. If demand is met by increased labour force participation then its value is, as above, the tax wedge on income. If it is met by withdrawing labour from other activities, then the value is the alternative wage. There is no net benefit if wages are the same in both jobs. Displacement is 100%, so demand induced employment effects should, from the national perspective, be ignored.

A qualification to this argument is conceptually important, although perhaps not quantitatively large for any single transport project. To draw labour from other activities there may have been an increase in wage rates in the area affected or more broadly. Given the level of productivity, an increase in wages must be financed either by a reduction in profits (or more generally, payments to other inputs), or by an increase in prices. The increase in wages is therefore just a transfer, of no value to aggregate income, unless the people paying for it (consumers and recipients of profits) are, for some reason, people that we do not value. A standard approach would be to suggest that benefit arises to the extent that the increase in price is paid by foreigners, i.e. represents a terms of trade improvement, so the country is able to sell its exports at higher price. This is an additional source of benefit, although one that is unlikely to be quantitatively significant for any single transport project.

Predicting quantity changes

Preceding sections of this paper have concentrated on the sources of wider benefits and the way in which they can be valued. To apply this in appraisal requires that forecasts can be made of the quantity changes (changes in investment, output and employment, as well as changes in traffic) that are likely to follow from a transport improvement, and which drive the wider impacts. These quantity changes are principally in the neighbourhood of the project, but may also occur elsewhere in the economy, important for establishing displacement effects. There are several – complementary – ways of getting the information required to forecast these quantity changes. One is from the technical details of the project itself. This can be combined with knowledge about the characteristics of the areas and sectors affected. Another is from spatial modelling, computing effects on activities throughout the economy. All approaches need to draw on past experience – both from case studies and from econometric analyses.

Project information

Standard project documentation contains forecasts of levels and changes in generalised transport costs and traffic flows (albeit, often derived with an assumption of fixed land-use). These are necessary to compute the user-benefits of a transport improvement and – with the assumption that all other changes are of zero social value – are also sufficient. To what extent is the information needed to calculate wider benefits contained in this documentation?

First, consider productivity effects. Recall that these operate through two distinct mechanisms, static and dynamic. The former is the change in 'distance' (as measured by generalised transport costs), given the location of economic activity; evidently, this information is available from project documentation. The second is the change in economic activity (perhaps as measured by employment, either in aggregate or by sector) in places affected by the project. In some projects information about this is implicit in the project specification. A commuting project contains estimates of the capacity change in the system and hence forecasts of passenger flows. If people are commuting to jobs then the response of employment in each place is implicit, if not explicit, in the passenger forecasts. Furthermore, the characteristics of the place served by the project are known, and forecasts of agglomeration and productivity effects follow from this. The appraisal of London's Crossrail project was based on information of this type (see Box and Worsley 2011).

Similar arguments apply to other projects that lead to land-use change. If a project unlocks residential development or is intended to lead to redevelopment of an urban area, then the planning system has projections of changes in residential and commercial land-use. These should be used in transport appraisal, both in order to get accurate traffic flows, and to evaluate the combined impact of the transport project and other dependent development. As suggested in the section on land use, the wider benefits of changes in 'attractiveness' should be based on estimates of expenditure created in dependent developments, estimates that will have been made during design phases of the project. The issue is therefore, not whether the relevant information exists, but ensuring that it is used in transport appraisal.

The third category of wider impacts occur in the labour market. Labour supply – changes in participation rates or moves to more productive jobs – are inherently local and project specific, and follow from information discussed in the preceding two paragraphs (see the Crossrail example in the Box). By contrast, labour demand is more likely to impact through the national labour market and, as suggested above, is likely to displace workers from other jobs.

Box 1. **Commuting to a cluster: Crossrail**

One of the objectives of Crossrail was to increase employment in central London. This, it was suggested, could lead to two sorts of wider benefit. By expanding employment, productivity in the cluster would increase. And there would be a ‘move to more productive jobs’, as workers in central London earn on average 20% more than workers in outer London.

To capture the first of these, studies took an elasticity of productivity with respect to employment of 0.06 and employment growth of 5% giving members of the cluster an average productivity increase of 0.3% (=0.06x0.05), the present value of which equals around 2/3rds of estimated user-benefits. (These numbers are illustrative of the range of cases used in the appraisal). Movement to more productive jobs raises GVA, but only a fraction of this is an increase in real income (welfare). An indifference condition means that the wage differential between central and outer London is matched by the commuting costs of reaching central London. However, individuals’ calculation of the net gain from switching jobs is based on post-tax income, not the pre-tax wage. Tax on the incremental income accrues to government, and it is this wedge that constitutes the net social benefit. This revenue effect (=real income gain) adds a further amount to the appraisal, worth somewhat more than user-benefits.

Crossrail appraisal provides a clear cut example of how to calculate wider impacts in a project specific manner, although it rests on some fine judgements. For example, the quantity effects come directly from the increased capacity of the commuter network. In other cases it might require a fuller modelling exercise, such as use of a LUTI model or similar. The example assumes that additional workers in central London add to cluster of activity and raise productivity, but the displacement of workers in outer London (or wherever they ultimately come from as equilibrium effects work through the economy) has no offsetting negative productivity effect elsewhere.

Calculation of the value of ‘moves to more productive jobs’ requires information on jobs created and displaced, the wage and productivity levels of each, and a narrative indicating why, in the initial situation, workers were not taking the higher wage and productivity jobs (i.e. why comparable jobs with different wages could co-exist). These elements were all present in the Crossrail appraisal, with commuting costs the barrier to taking the jobs, and fairly clear cut wage differentials. In other contexts these differentials are likely to be much smaller and harder to identify.

Econometrics

Project specific and local information needs to be combined with evidence, derived from econometric analyses and from case studies. Such evidence makes three principal contributions. The first is to provide the elasticities – responses of one variable to changes in another – on which analysis is based. Traffic forecasting is dependent on such elasticities, and so too are the wider benefits mechanisms of productivity (as discussed in Appendix I), surplus derived from consumer demand systems, and labour force participation. A second contribution comes from the aggregate studies of the role of transport infrastructure on economic performance. These are in the tradition of Aschauer (1989, 1990), and summarised in the meta-study of Melo et al. (2013), suggesting that elasticities of private output with respect to the stock of transport infrastructure are positive but small, around 0.1 or less. These studies are too aggregate to provide precise estimates of effects of particular projects but are useful as a reality check, setting bounds against which estimates of effects of particular projects should be compared.

The third contribution comes from studies of the effects of particular transport improvements. Such studies – be they descriptive case studies or econometric analyses – are fraught with methodological difficulties. Above all, it is difficult to establish the counterfactual, of what would have happened in the absence of the project. New lines of research are making progress on this by comparing areas that are 'treated' by a transport improvement with areas that are similar but 'untreated'. [12] Comparison of treated and untreated areas still poses an identification challenge, as it is hard to establish that transport investments played a causal role in emergent differences between the areas. Did a region boom because a road was built, or was the road built because of an anticipated boom? The literature is getting to grips with these issues by a combination of use of instrumental variables and searching for 'natural experiments' (situations where a transport investment was made for reasons uncorrelated with expected economic performance). Significant positive effects of transport infrastructure are found for studies as diverse as Chinese railways and roads in the US and the UK. Problems remain however. Studies typically compare treated and untreated areas, a method that provides no way of splitting effects between positive impacts in treated areas and negative impacts (e.g. due to displacement) in untreated areas. There is also the inherent difficulty of generalising from one case study to the particular circumstances of a new project. But despite these difficulties, progress is being made and it can be expected that accumulation of a large set of high quality studies of past projects will usefully inform the design and likely impacts of new projects.

Spatial modelling

Spatial modelling pulls together project information and data from other sources into a formal structure in which the effects of a project can be simulated. Two frequently used techniques are land-use transport interaction (LUTI) models and spatial computable equilibrium models (SCGE). The advantage of such models is that they are able to give a fuller spatial picture of the impact of a project, and incorporate general equilibrium responses in both product and labour markets. LUTI models generally have much finer spatial structure than SCGE, while SCGE allow for equilibrium response in more variables.

As noted above, these models are expensive, and not therefore appropriate for most relatively small scale projects. They are, in many cases, taken 'off-the-shelf', and applied with insufficient attention to all the salient features of the project and situation that they are analysing. There is always a risk that undue weight is placed on estimated effects, even if these are driven by parts of the model that are not widely understood or subject to critical evaluation.

Nevertheless, such models potentially play a valuable role. In particular, they can be employed to develop alternative scenarios of the effects of a project. As we have argued, outcomes vary with the range of complementary policies that accompany a transport improvement, and with private sector responses. There are inherent uncertainties about private sector responses – particularly where these are potentially transformative, and involve some of the positive feedback mechanisms that are associated with wider benefits. These alternatives are best captured by presenting results for a range of scenarios, and formal computable models are well placed to do this.

Table 1 offers a summary of circumstances in which formal modelling may be an important part of establishing wider impacts, and circumstances where project information and econometric and case study knowledge is likely to be sufficient.

Table 1. Predicting quantity changes

	Scope of appraisal	
	Local project information:	**Spatial modelling:**
User benefit	User benefits	No: (induced quantity changes are of zero value)
Productivity	Static clustering	No: (changes in 'distance' given employment)
	Dynamic clustering	Yes: If likely displacement of activities with agglomeration potential
Investment and land-use change	Residential	No: (quantities set by constraints elsewhere)
		No: If activity change determined by project design/ capacity
	Commercial	Yes: If likely displacement of activities with similar market failures
Employment	Participation & better jobs	No: (local effects only)
		Yes: If regional distribution is of interest.
	Unemployment	Yes: If displacement < 100%

Displacement

Finally, we return to the question of displacement, occurring if expansion of activity in one area is at the expense of contraction elsewhere. Is formal modelling necessary to capture displacement effects, or can judicious use of information about the project and its context provide sufficient guidance?

The two main channels through which displacement occurs are the labour market and product markets. If a transport project generates investment that creates new jobs, where do the workers come from? Some may come from increased labour force participation, a (local) supply response discussed above. Otherwise, the default position is that they are displaced from jobs elsewhere in the economy. The basis for this judgement is the view that in reasonably well functioning market economies employment – over the long run – is close to some natural rate. Displacement of 100% implies that employment effects are of zero value, so can be ignored – although it may be of interest to report them by sector or by region, and it is possible that policy makers put particular value on additional employment in some sectors or regions.

Turning to product market mechanisms, the issue is whether investment following a transport improvement is additional, or simply a relocation from another place where the activity was of equal value. For activities that are perfectly tradable internationally displacement it likely to be zero; if an internationally mobile vehicle assembly plant is choosing between two different jurisdictions, then the jurisdiction that attracts it is unlikely to see other vehicle assembly activity displaced.

For non-tradables the default position is reversed. A retail development is, to a large extent, drawing custom away from other locations, so displacement is high. Judgement then needs to be exercised as to impacts on the attractiveness of different locations. There may be threshold effects, so that large scale redevelopment of one area may bring the effects outlined in the section on land use while displacement is spread widely, only having marginal effects on other areas and not leading to equal loss of attractiveness. Thus, developing a cluster of activity – e.g. in financial services in the City of London – might draw financial service workers from elsewhere in the UK, but does not undermine another UK financial services cluster.

It is evident from these arguments that displacement effects are highly project and context specific. This reinforces the need to appraisals to be related to the strategic narrative on the project, backed up by knowledge of the sectors and markets that are likely to be affected.

Summary and conclusions

Transport investments can deliver economic benefits over and above conventionally measured user-benefits. They arise as (1) transport fosters intense economic interaction that raises productivity; this can occur in clusters within narrowly defined areas or more widely by linking areas. (2) Transport shapes the level and location of private investment, unlocking residential development and triggering large scale redevelopment of urban and other areas. (3) Transport impacts the labour market, potentially enabling more workers to access jobs. These impacts can yield real income gains, particularly where transport induced investments interact with market failures associated with increasing returns to scale, obstacles to efficient land use, and labour market imperfections.

Appraisal of transport projects has to combine relevance with rigour. Relevance requires context specificity. There should be a clear narrative of what each project is expected to achieve, and appraisal should capture the causal channels through which the project is expected to have impact. This suggests a modular approach (along the lines followed in this paper and summarised in Figure 1). To maintain rigour, and comparability across projects, modules need to be based on a consistent set of principles. These should be grounded in economics and directed at identifying changes in real income (welfare). This means being careful to identify quantity changes throughout the economy. The value of such changes turns on market failures of some type, and need to be referenced against a benchmark of the 'perfect' economy in which small changes are of zero social value.

Some mechanisms and associated appraisal modules are quite well developed and have sound evidence base, notably those to do with proximity and productivity, and with labour force participation and employment. Others, to do with land-use change, dependent development and coordination failure are still in need of further refinement. Such work is relevant not just for appraising transport projects, but for appraisal of micro-economic policy change more broadly.

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Appendices

Appendix I. Accessibility and productivity

Table A.1 reports elasticities of productivity with respect to economic mass. It is not intended as a definitive statement of parameter values but is indicative of the magnitudes and illustrative of the issues.

In the first block of the table the units of observation are places. Results are reported from survey article (Rosenthal & Strange 2004), the US (Ciccone & Hall 1996) and the UK (Rice et al. 2006). Controlling for skill and, in Rice et al. also factoring out differences in occupation structure, researchers find elasticities in the range 0.03- 0.04. Rice et al. also estimate, rather than impose, the rate of spatial attenuation of effects; they tail off sharply beyond about 45 minutes driving time, i.e. are concentrated within travel-to-work distances.

The second block is representative of studies based on firm level data (for the UK, plants from the Annual Respondents' Database). The study by Graham et al. (2009) estimates productivity relationships by sector, using an *ATEM* computed for the location and sector of plants and offices. Elasticities of similar magnitude are derived from this work, and there is considerable heterogeneity, with effects largest in business services. The spatial decay factor was estimated separately for each sector and is largest in service activities, suggesting the incentive for tightly concentrated service clusters. This study provides the elasticities generally used in UK DfT appraisals.

The third block of table A.1 reports results of estimating wage equations, i.e. looking at the determinants of the earnings of individual workers. The three studies indicated are for data from France, Spain and the UK. Working with individual data makes it possible to address the issue of 'people versus place' by using a fine level of worker level controls – generally skills, age and experience. Once again, elasticities of productivity are of similar size, with those for France (Combes et al) and Spain (Puga & Roca) at 0.046 and 0.05 respectively.

The studies in the third block contain two important extensions. One is that while some characteristics of individual workers are observable – their age, skill and experience – their innate ability is not. Bias is introduced if there is a selection effect such that people with high innate ability are more likely to move to large cities. Individual fixed effects control for this, with identification coming from tracking individuals who move. Estimates of this type are presented in the final row of each of these studies and in most cases markedly reduce the productivity elasticity. For Combes et al. (2008) and for Puga & Roca (2012) including these individual effects approximately halves the elasticity, although still leaving it within the range put forward in earlier studies.

The second extension is that the work by SERC (2009) has richer modelling of access to economic mass, constructing *ATEM* measures separately for two different modes of transport (car and rail) and estimating the joint effect of both measures on wages. Consistent with the results above, they find that controlling for the observable characteristics of individuals (and jobs) reduces the effect of access to economic mass (by somewhere between a quarter and a third). The effect of controlling for unobservable characteristics depends on whether one is considering the impact of accessibility by car or by train. For accessibility by car, allowing for sorting on the basis of unobserved characteristics increases the estimated effect (and turns it significant). In contrast, for accessibility by train allowing for sorting decreases the estimated effect by a factor of 3 (larger than the reduction found in studies that do not split by mode).

Table A.1. **Accessibility and productivity**

Unit of observation: **Places**	**Elasticity of productivity with respect to ATEM**	**Controls**		**Distance measure: Spatial decay**
Rosenthal & Strange (2004)	0.05 - 0.11	--- Survey article ---		
Ciccone & Hall (1996)	0.03	Education level		Fixed
Rice, Venables & Pattachini (2006)	0.04	Occupation, skill		Travel time. Estimated.
Unit of observation: **Firms**				
Graham et al. (2009)	Econ average: 0.043 By sector: Manuf: 0.021 Construction: 0.034 Cons. servs: 0.024 Bus. servs: 0.083	Firm characteristics (e.g. firm age)		Geographical distance. Estimated.
Unit of observation: **Workers**		Observable (occupation, age, skill, experience) [2]	Unobservable (individual fixed effects) [2]	
Combes et al (2008)	0.035	√	X	Fixed
	0.024	X	√	
Puga & Roca (2012)	0.046	√	X	Fixed
	0.023	√	√	
SERC (2009)[1] Car	0.08 (not signif)	X	X	GTC car. Fixed, reciprocal
	0.05 (not signif)	√	X	
	0.07	√	√	
SERC (2009)[1] Rail	0.258	X	X	GTC rail Fixed, reciprocal
	0.17	√	X	
	0.05	√	√	

1: SERC 2009, columns 1, 5, 6 table 8 p49.
2: √, control included**:** X, control not included.

Appendix II. Investment and land-use change

Residential development: The change in welfare (to a first order approximation) is the rule of half, plus the quantity change times the average price cost margin,

$$\Delta W = \Delta T\{Q_0 + (Q_1 - Q_0)/2\} + (Q_1 - Q_0)(p_1 - c_1 + p_0 - c_0)/2 .$$

The text refers to the two elements as UB and WB respectively. Rearranging,

$$\Delta W = -\Delta t.Q_0 + (Q_1 - Q_0)(p_1 - c_1 + p_0 - c_0 - \Delta t)/2$$

Land value uplift is the change in price times initial quantity, plus the additional quantity times the new price minus its average opportunity cost (construction cost plus value of land in previous use)

$$\Delta V = (p_1 - p_0)Q_0 + (Q_1 - Q_0)(p_1 - (c_1 + c_0)/2)$$

Land value uplift measures the change in welfare, $\Delta V = \Delta W$ if and only if $p_1 - p_0 = \Delta t$, i.e. the change in price is equal to the user benefit, and not influenced by the change in quantity supplied.

Commercial land-use change: For an iso-elastic demand curve, $x = p^{-\sigma}$, expenditure is $px = p^{1-\sigma}$ and consumer surplus (CS) is the integral of the area below the demand curve and above price, $CS = p^{1-\sigma}/(1-\sigma)$, from which the ratio of consumer surplus to expenditure is 1/(1-σ). For fuller treatment, with many varieties and a spatial structure see Fujita et al. (1999).

Notes

1 For fuller discussion of the issues in this paper and their relationship with UK practice see Venables et al. (2015).

2 Throughout we focus on the effects of the completed project. We do not investigate the construction costs of projects, nor include the temporary economic activity created by construction.

3 Of course, they do not necessarily accrue to the user as e.g. they may be shifted to rents and captured in land value appreciation.

4 Duranton and Puga (2004) survey these ideas.

5 The economics literature often models this as the presence of a large 'variety' of intermediate inputs. Each variety yields consumer surplus that is not captured by the supplier (i.e. the supplier cannot perfectly price discriminate). See the next section for further development of this idea.

6 See for example, Audretsch and Feldman 2004, Glaeser & Gottlieb 2009.

7 Elasticities are therefore in the range 0.05-0.1 since 2^(0.05)=1.03 and 2^(0.11) = 1.08.

8 Owner occupiers of existing houses being indifferent about the division.

9 A statement of the issue is given by Simmonds (2012): "if a transport change improves access to a town centre and causes an increase in demand for shopping and services there, this is likely to lead to an improvement in the retail offer of that centre, which will be an externality benefit to residents with easy access to that centre". See also Martinez and Arraya (2000), Geurs et al (2006; 2010).

10 This is based on Venables (2016)

11 See Mankiw and Whinston (1986) for the possibility of welfare loss when products are perfect substitutes.

12 Redding and Turner (2014) survey some of this literature. Methodologically there is a parallel with drug trials: some areas are 'treated' by having investment, others form the control group. However, it is not generally the case that assignment of areas for treatment is random, as it would be with individuals in a drug trial. Instrumental variables are used to address this problem. See Baum-Snow (2007), Donaldson (Forthcoming), Duranton and Turner (2012) for good examples of the approach.

International Transport Forum

International Transport Forum
2 rue André Pascal
F-75775 Paris Cedex 16
contact@itf-oecd.org
www.itf-oecd.org