

Transport investment and economic performance: a framework for project appraisal

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ABSTRACT

The case for major transport investment is frequently made in terms of impact on economic performance. A recurring difficulty faced by policy makers is a disjoint between this motivation and the cost benefit analysis, which may be too narrow. Broadening the set of economic mechanisms studied creates the risk that bad arguments are legitimised and effects can be exaggerated. There is a need for an appraisal framework that ensures all relevant impacts are captured, ensures the opportunity cost of drawing more resources into an activity is identified and meets the needs of the different audiences of the appraisal. There is a need for context specific appraisal. Central to the impact on economic performance is how private sector investment responds to changes in accessibility. Investment in one location can improve productivity, create growth, but may also displace output and employment elsewhere. We group impacts within the framework into four types: user-benefits, proximity and productivity effects, investment and land use impacts and employment effects. Within each of these groups there are a series of transport-economy mechanisms which become relevant in different contexts. Some of these mechanisms are well established and are applied in practice. Others still are more challenging and need to be the subject of further research. Throughout, improvements in the evidence base are needed.

Key words: transport appraisal, wider economic impacts

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1 INTRODUCTION

The case for investment in major 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. 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.

Unsurprisingly therefore, studies that examine the role of CBA in transport investment decision-making have found that it can have little or no impact on decision-making (Nilsson, 1991; Fridstrom and Elvik, 1997; Odeck, 1996; Eliasson et al., 2013) or that only certain elements of the CBA seem to matter (Nellthorp and Mackie, 2000; Odeck, 2010; Eliasson and Lundberg, 2013). Arguably, even with the most developed appraisal systems a 'good' CBA is at best a hurdle that has to be cleared (Eliasson and Lundberg, 2013; Eliasson et al., 2013; Kelly et al., 2015). This is also seen in England where projects are ascribed value for money criteria which influences the likelihood of a project being funded. Ultimately this marginalisation of CBA can result in politicised decision-making and potentially bad decisions. Decision-making is undertaken by a very heterogeneous group and within that group there exist philosophical differences in the approaches of economists, planners and politicians (Mouter et al., 2013; Eliasson et al., 2013). One solution to bridge the differences between the groups is to extend the CBA to incorporate wider economic impacts, while remaining firmly grounded in careful analysis of the impact of projects on welfare, as is attempted in the UK (see e.g. SACTRA, 1999; DfT, 2005). Then even if the value of wider economic impacts turns out to be small, the appraisal has engaged with the arguments put forward by scheme promoters and local interests and runs less risk of being marginalised.

Internationally, development of transport appraisal guidance in this area remains limited (for surveys see Odgaard et al., 2006; Mackie et al., 2014). 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 the quite different impacts of e.g. 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 relieving traffic congestion or 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.

The focus in this paper is on wider economic impacts. That is not to say that social, equity and environmental impacts additional to user-benefits do not occur, but they are addressed elsewhere in the literature on appraisal. There are of course inter-relationships between wider economic, social, equity and environmental impacts – an example would be a transport investment that reduces unemployment in a remote region having wider economic, social and equity impacts. We do not delve into these inter-relationships beyond observing that, as with the treatment of wider economic impacts, double counting of the same benefit has to be avoided. Our focus here is on the correct treatment of wider economic impacts in an appraisal including avoiding double counting both between wider economic impacts and user benefits and between different wider economic impacts.

This paper sets out and discusses the key components of this approach. The next section, Section 2, presents the mechanisms that comprise the framework grouped into: user-benefits: proximity and productivity due to agglomeration: induced investment and land use change: and employment. It discusses the concept of a context specific appraisal in which the analyst focuses on the mechanisms of relevance in the analysis. Section 3 of the paper then sets out three key challenges to the

implementation of the framework, whilst the final section, Section 4, presents some concluding remarks.

2 THE FRAMEWORK

2.1 The effects of a transport improvement

A transport improvement brings time and cost savings to users of the transport network.¹ 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. 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 project².

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.

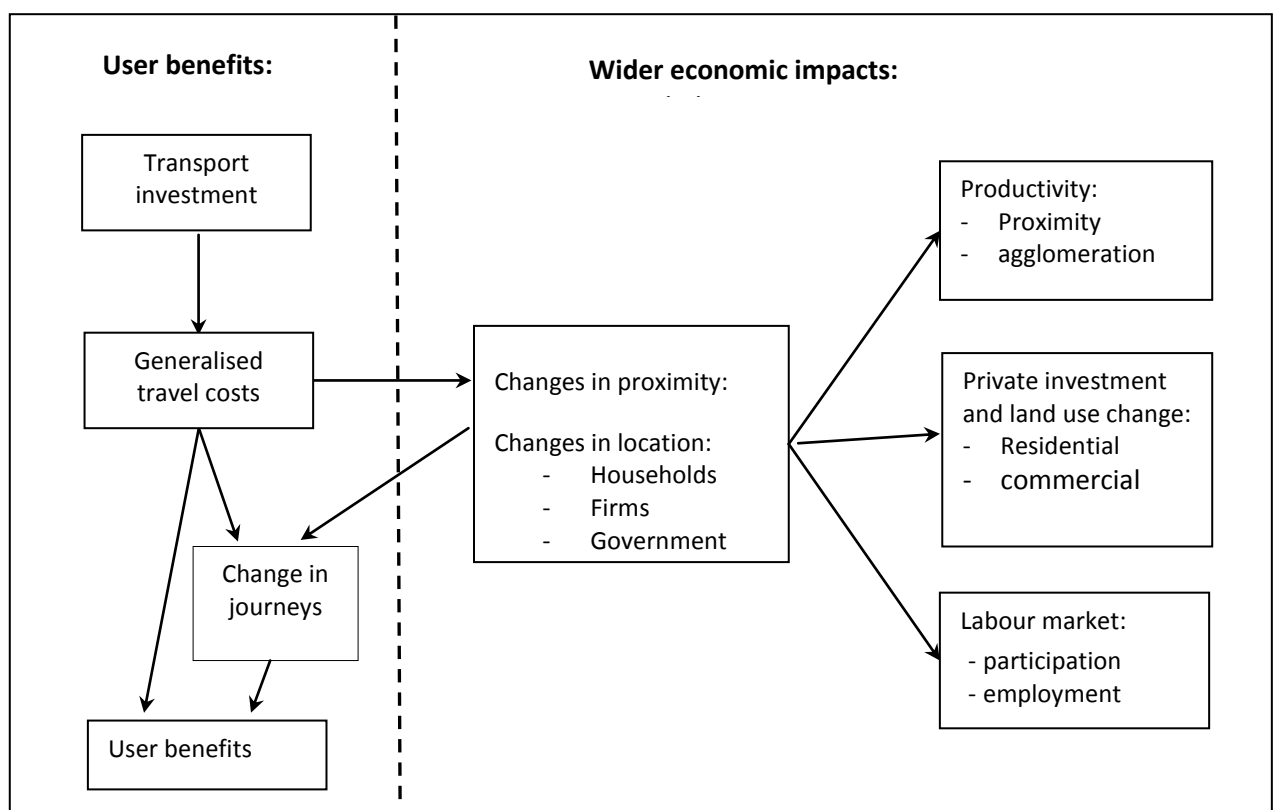
¹ Throughout we focus on the effects of the completed project. We do not investigate the construction costs of projects, nor include the temporary economic activity created by construction.

² 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.

Third, there may be impacts in the labour market, on 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.

Of course, there are links between all these mechanisms. A transport improvement might induce private investment, raising employment, creating agglomeration effects and feeding back into traffic flows. Distinguishing between the different mechanisms that may create welfare gain is conceptually important, while in practise care must be taken not to double-count effects.

Figure 1. The effects of a transport improvement



Note: Feedback effects are excluded for clarity

To include these impacts in transport appraisal two economic 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 due to concentration on effects in the neighbourhood of the project.

The remainder of this section looks in turn at each element of this framework starting with user-benefits.

2.2 User-Benefits

The core of an evaluation is the benefits and costs accruing to users of the transport system. This is the primary activity in which the policy intervention acts. Evidence to date suggests that these benefits form the largest component of benefit of infrastructure investment. In fact when markets are working perfectly and changes are small the benefits accruing in the transport system are all that need to be considered as marginal costs and benefits equal each other in the inter-related secondary markets.

Accurate measurement of user-benefits can be challenging and considerable effort is often expended in calculating travel demands, travel times and costs. A change in quality and cost of travel leads to substitution between routes, time periods, origins, destinations and mode. Travel demand may also grow in absolute terms – both in terms of number of trips and/or in distance travelled. Underlying these changes are a whole host of behavioural decisions including where to trade, who to trade with, and where to shop, work, or live. Generalised travel costs comprise both the direct user experienced monetary costs of operating private vehicles, road charges and public transport fares, as well as non-market goods such as time, comfort and reliability. Shadow pricing of these non-market effects is therefore critical to the accurate measurement of generalised transport costs and hence user-benefits.

The quantity changes in travel demand, travel time and reliability, etc. in combination with the observed market prices and shadow prices are used to value the real income gain of the transport investment. When the changes are small this can be approximated using the rule of half.

$$User\ Benefit = \frac{1}{2}(T_1 + T_0)(GTC_1 - GTC_0),$$

where T_0, T_1, GTC_0 and GTC_1 are the travel demands and generalised travel costs before and after the transport investment.

Two further comments are noteworthy. First, elements of generalised travel costs may be shadow priced to incorporate external effects that may go beyond those immediately experienced by transport users. These include costs of local pollution such as noise and particulates, and of CO2 emissions and global environmental damage. Second, user-benefits may be associated with productivity increases. This is because physical assets such as rolling stock or road haulage vehicles can be used more efficiently if trips take less time, and similarly the usefulness or productivity of travel time depends on comfort, reliability, service frequency, and so on. These effects are valued in generalised travel costs; a cost saving in road haulage and a productivity increase in vehicles are just two names for the same thing. They are not to be confused with external economies of agglomeration and productivity, as described in the next sub-section.

2.3 Proximity and productivity due to agglomeration

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, Australia, New Zealand, Sweden and different US states (Mackie et al., 2014).

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.³ These may be technological (i.e. effects not intermediated through a market, such as knowledge spillovers) 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 other firms – the

³ Duranton and Puga (2004) survey these ideas.

specialist components, and engineers, lawyers, finance experts who may be necessary to efficient operation of a firm.⁴ 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, such as automotive clusters in developed countries, and clusters in labour intensive sectors such as textiles and garments in developing countries. 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 activities⁵.

A substantial econometric literature quantifies the relationship between productivity and economic mass and a reasonable consensus has emerged on the magnitude of the 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- 0.11⁶. This is a

⁴ 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.

⁵ See for example, Audretsch and Feldman (2004), Glaeser & Gottlieb (2009).

⁶ Elasticities are therefore in the range 0.05-0.08 since $2^{0.05} = 1.03$ and $2^{0.11} = 1.08$

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) suggests that the mean estimate of this elasticity across thirty four studies which provide more than seven hundred elasticity estimates is somewhat lower, at 0.03, although points 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 (see Combes and Gobillon 2015). At the sectoral level, there is evidence of heterogeneity, with business services and high technology sectors exhibiting the largest localisation economies.

Transport is a necessary ingredient to securing these benefits, in three distinct ways.

- i. Economic interactions between firms (and between firms and consumers) are more intense the better the transport system. Firms can reach wider markets, enabling them to expand, gain scale economies and develop specialist skills; markets are more competitive as the natural barrier of distance is reduced and inefficiencies associated with monopoly and monopsony power are eroded.
- ii. Transport enables cities to specialise, developing sector specific advantages. Historically this was manifest in cities specialised in textiles, steel or cutlery. While some manufacturing clusters are still important, the phenomenon is now apparent in service sectors, particularly knowledge intensive activities. If better transport or communication enables some of the ancillary activities to be 'outsourced' to another city, it reduces costs and creates space for the high-value activities to further concentrate in the central cluster.
- iii. Transport is necessary to get workers into concentrated and productive centres of activity. This is most apparent in commuting into central business districts, but there is also evidence that firms outside these districts benefit from drawing on a wide catchment area of employees.

While there is a single underlying mechanism at work in each of these cases – concentration of economic activities leads to high productivity – the precise role of transport is different in each. Effects vary across transport projects (e.g. commuting versus inter-city links) and across the areas, and sectors likely to be affected.

2.4 Induced investment and land-use change

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. These benefits feed through into secondary markets stimulating investment by either lowering marginal costs or increasing the return. This response changes traffic flows, changes which should be included in calculation of user-benefits. The investment would also be expected to increase output (GDP). 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 the conditions necessary for induced changes in quantities (of outputs and inputs) to yield net economic benefit, and then at changes in land use – such as city centre redevelopment – for which transport improvement is the catalyst.

Increased output

In undistorted secondary markets marginal benefits equal marginal costs. For small changes in quantities supplied and demanded in the secondary markets there is no additional benefit to transport user benefits. In distorted markets however marginal benefits of increased output exceed the marginal cost of supplying them and there is an additional surplus, which can be relevant in a transport appraisal context (Venables and Gasiorsek, 1999). Market power is prevalent in many sectors; studies have shown large variations by sector and by country with the service sector exhibiting higher mark-ups than manufacturing in the EU, whilst the opposite is the case in the US (Badinger, 2007; Christopoulou and Vermeulen, 2012).

This heterogeneity makes clear the importance of context specificity. Mark-ups differ between sectors and there will be net gains only if expanding sectors have larger mark-ups than those from which activity is displaced. This context specificity is likely to be most obvious between transport investments in cities containing high mark-up tradable services, compared to those in remoter regions dominated either by manufacturing or extraction of primary goods (oil and gas).

Displacement can occur through different channels. It may arise directly in the product market (particularly for non-traded goods) or through general equilibrium effects and competition for scarce factors of production.

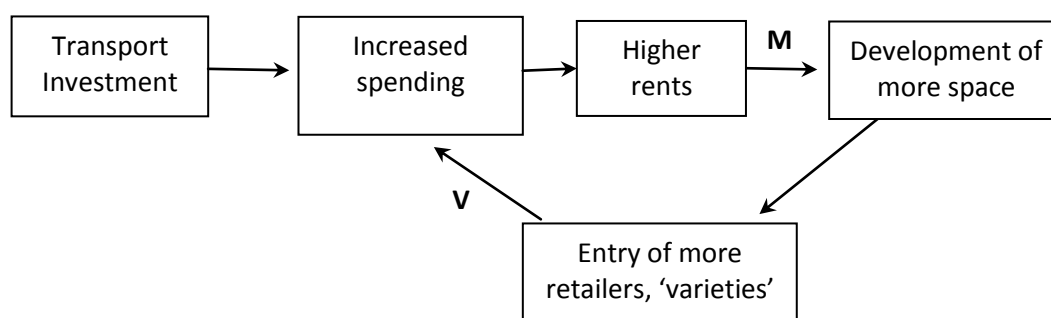
Land-use change

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’⁷. Under what circumstances do these benefits exceed the user-benefits received by travellers 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.⁸ 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. Land use change in a commercial development



User-benefits trigger this process, and wider-benefits arise if (and only 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.

⁷ 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).

⁸ This is based on Venables (2016) and adds some micro-economic detail to the model of Harris and Wilson (1978).

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 $1/(\sigma - 1)$ ⁹. Hence, the value of any variety effect is equal to the change in expenditure divided by $(\sigma - 1)$. If products are perfect substitutes – the retail development just means more identical stores – then σ is infinite, there is no increase in ‘attractiveness’ and no welfare effect.¹⁰ 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 can be calculated 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 above is 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

⁹ 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 $1/(1-\sigma)$. For fuller treatment, with many varieties and a spatial structure see Fujita et al. (1999).

¹⁰ See Mankiw and Whinston (1986) for the possibility of welfare loss when products are perfect substitutes.

– 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 now turn to the other possible source of market failure, the presence of barriers to development, M. This is applicable to both commercial and residential developments. A number of sources of market failure may be possible. There may be monopoly power as a developer perceives that building extra space reduces rents, or 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 or workers. In both situations 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 section 2.4) 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. Transport infrastructure may act as a catalyst in a growing city as signal that a location will develop or in a regeneration environment¹¹ by for example increasing property prices and thereby increasing the return to property improvement.

2.5 Employment

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.

¹¹ Subject to other conditions of growth being met – primarily the availability of appropriately skilled labour.

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 distortion has received little attention in appraisal practice – for example Mackie et al. (2014)'s survey finds that only the UK appraisal practice includes this tax wedge effect in guidance.

Similar principles apply if transport triggers a densification of commercial land use - for example around city centre train stations. Workers may now prefer to commute to a higher paid city centre job than have a lower paid job in the suburbs. 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.

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 in the absence of the jobs created. For long-run transport projects in reasonably well functioning market economies it is likely that the labour market will adjust to some 'natural rate' of employment 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.

The argument differs if some market failure leads to persistent involuntary unemployment and transport induced job creation reduces this level of unemployment. The value of output (and of 'leisure') foregone is then less than the value of output in jobs created, and there may be additional social benefits from lowering unemployment. These effects are important in developing economies, as well as in regions of developed economies that have significant structural un- (or under-) employment.

One further point is conceptually important, although perhaps not quantitatively large for any single transport project. To draw labour from other activities there may have to be 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.

2.6 Context specific appraisal

Transport appraisal needs to be proportionate. It would clearly be highly resource intensive and unnecessary to research the impacts of all the economy mechanisms discussed as part of every transport appraisal. Context specific appraisals that focus in on the relevant economy mechanisms are therefore necessary (see Table 1). A significant expansion of city centre rail connectivity serving a major urban centre with strong growth (e.g. Crossrail and Canary Wharf, London) would for example focus on the economy mechanisms: user-benefits, dynamic productivity growth through employment changes and the tax wedge from the move to more productive jobs. This is because the strategic narrative underlying the project is one about facilitating employment growth and productivity in Central London by increasing rail capacity and commuting opportunities which are currently constraining growth.

Contrastingly the strategic narrative behind inter-city connectivity such as a high speed rail line is often one of increasing business efficiency and initiating land use change around the stations. This points towards a context specific appraisal that would focus on user-benefits (including productivity increases due to increased specialisation), barriers to development and the benefits of land use change. The strategic narrative for step changes in inter-urban connectivity between rural/peripheral regions and core regions is often one associated with promoting economic growth

in core industrial sectors typically primary sector (e.g. oil and gas industry, fishing, etc.) and related manufacturing (e.g. in food and drink). A context specific appraisal would therefore focus on user-benefits, productivity benefits through increased specialisation, increased output in imperfect markets (should the sectors in the regions affected exhibit imperfect competition) and benefits from increased/displaced employment (should the regions affected exhibit imperfect labour markets).

Table 1: Economic impact and transport-economy mechanism

Economic impact	Mechanism		Valuing	
			Welfare	National GVA
User-benefits	Firms ¹	Δ GTC leads to Δ cost / price	✓	✓ ⁵
	Households	Δ GTC leads to Δ time/quality/cost	✓	---
Productivity due to agglomeration	Static (larger markets)	Δ Economic mass (with fixed land uses and Δ GTC) changes productivity	✓	✓
	Dynamic: clustering and increased specialisation	Δ Location/ activity levels of sectors. Cluster formation raises productivity	✓	✓
Induced Investment and land use change	Increased output ²	Δ Q x Displacement (0-100%)	---	✓ ⁵
		Δ Q and imperfect competition x Displacement (0-100%)	✓	✓
	Land use change	Increased varieties/attractiveness (land use externality) x Displacement (0-100%)	✓/--- ³	✓/--- ³
	Barriers to development	Market failure in the planning regime x Displacement (0-100%)	✓	✓
		Coordination failure	✓	✓
	Multi-sectoral investment	Complementary policies reinforcing each other. Partial equilibrium analysis is inappropriate – examine land value uplift or use multi-market methods x Displacement (0-100%)	✓	✓
Employment	Labour supply	Δ labour supply function due to lowering barriers to work (market failure is tax on income)	✓	✓ ⁵
	Labour demand	Move to more productive jobs (market failure is tax on income)	✓	--- ⁶
		Reducing unemployment in areas of high unemployment (structural employment, market failure in the labour or housing markets) ⁴	✓	---

Notes: (1) Δ GTC – generalised transport costs; (2) Δ Q – change in output; (3) land use externality can be related to the agglomeration externality and the analysis must be structured to avoid double-counting; (4) If labour is displaced from an area experiencing similar market failures, as may be obvious from similar levels of unemployment, then displacement effects also need to be taken into account. (5) Care needs to be taken to avoid double-counting GVA impacts; (6) GVA impact included in dynamic productivity effects due to changes in employment

3 THREE CHALLENGES

The economic framework set out in the previous section focuses on the mechanisms by which a transport investment delivers economic performance and how that performance can be valued within the context of an appraisal proportionate to the scale of the investment. In implementing an appraisal there remain a number of challenges of which three stand out: the practicalities of using the agglomeration elasticity evidence base in an appraisal, the measurement of user-benefits with land use change and multi-sectoral investments, and the challenge of estimating the quantity effects on output and employment. The rest of this section takes each of these challenges in turn, setting out the issues and in places presenting tractable solutions until further research becomes available.

3.1 Productivity due to agglomeration

The underlying economic theory and empirical evidence on the relationship between productivity, agglomeration and transport is persuasive and its inclusion in transport appraisal practice is becoming standard in certain countries. Challenges, however, remain. There is a degree of consensus regarding how productivity varies with economic mass. Accessibility, as part of the economic mass ‘equation’, is part of that relationship— both empirically and theoretically. This is however subtly distinct from saying that if we increase accessibility and therefore economic mass we will get an increase in productivity. Ex ante transport appraisal methods employed in the UK, New Zealand, Australia and elsewhere simply assume that we will. Improved statistical methods that account for heterogeneity in labour and that use micro-level firm data increasingly produce lower estimates of agglomeration elasticities, and some advanced methods have not been able to distinguish the role of transport accessibility from other drivers of agglomeration “implying that the use of conventional point elasticity methods may be highly misleading” (Graham and van Dender, 2010). The issue is exacerbated by the lack of robust ex post data. The limited studies there have been have identified a positive change in productivity following transport interventions (What Works, 2015 pp26) – albeit these studies do not distinguish between productivity improvements due to user-benefits and those arising due to increased agglomeration. Better evidence of the ability of transport to deliver gains in productivity due to agglomeration is needed.

The transport market is heterogeneous. Different modes serve different destinations; travel conditions vary by mode and by time of day; and travel is made for a variety of different reasons (e.g. freight, business, commuting, leisure). The key questions then from a productivity and agglomeration perspective are whether some of these market segments are more important than others and if so by how much? Rail and public transport in general serve city centres which are a key driver to agglomeration related productivity gains, peak hour journey times are important for

commuting and labour market connectivity, inter-peak journey times are important for freight and business trips and the associated business to business connectivity, whilst non-work-other journey times are important in terms of market access and for education. The implication is that they are all important at some degree, but empirically they are unlikely to be of equal value – unless by coincidence. D’Costa et al. (2012) find some evidence of this variation by mode, but aside from that the literature is silent on the issue. Primarily this is due to empirical difficulties in separating out the contribution of different accessibility measures¹². Given this void transport appraisal practitioners have been reduced to combining generalised travel costs across modes and time periods on grounds of reasonableness, rather than evidence, when formulating the change in economic mass.¹³ Unfortunately subtle changes in the assumptions that underpin these calculations can give very different predictions of productivity gains. There is therefore an evidence gap regarding which transport market segments drive the productivity gains from agglomeration and how to aggregate generalised transport costs across these segments.

The empirical literature on agglomeration externalities points increasingly to the use of firm level microdata as the preferred data for estimating agglomeration elasticities. Furthermore methods used to control for endogeneity between accessibility and productivity have also led to the use of distance measures in the economic mass metric (see e.g. Graham, 2007, Graham et al., 2010). This creates a tension in a transport appraisal context at two levels. Firstly firm level data typically excludes the public sector – which in developed country economies can form a third of the workforce; whether or not this sector benefits from agglomeration economies is a moot point. Secondly a distance based economic mass metric is not sensitive to transport policy – aside from the obvious but rare estuarial crossing or mountain pass/tunnel type investments. In application appraisal practice has had to accommodate these difficulties. Guidance such as that in the UK does this by excluding productivity gains to the public sector and extrapolating the distance based agglomeration elasticities to generalised cost (DfT, 2014a), but clearly this is not ideal.

The increased interest in cluster formation and increased specialisation as a consequence of inter-city effects exposes further empirical gaps when attempting to translate theory into transport appraisal practice. We associate both localisation and urbanisation agglomeration economies with increased city specialisation arising from inter-city effects, but once again empirically we find that

¹² Typically locations that are well connected by one mode or in one time period are also well connected in other modes and time periods, leading to a lack of variation in observed data and difficulties separating out effects by mode and time period.

¹³ The UK Department for Transport for example excludes non-work other and freight travel times from the calculation, gives travel times by each mode and time period an equal weight (DfT, 2014a).

these effects are correlated making it empirically difficult to separately identify the urbanisation and localisation effects. The choice of different accessibility metrics in the economic mass variable is one approach that has been adopted Graham (2009) and as expected leads to lower estimates of agglomeration elasticities vis a vis studies that only identify either localisation or urbanisation productivity elasticities (Melo et al., 2009). The other part of the story is the ability to model how industrial composition will alter as a consequence of inter-city connectivity. Land Use Transport Interaction models (see Wegener, 2011 for a review) can be used to model how industry location changes giving rise to industrial clusters, but the recent research effort focused on identifying task specialisation within the service sector (Michaels et al., 2013) has not as yet been subject to any significant modelling effort.

3.2 Land use change and user-benefits

Behaviourally we associate transport investment with private investment decisions of business and households – as in Figure 1. This leads to land use change. We have also seen that land use change can generate an externality by changing the attractiveness of an area. In the political landscape transport infrastructure typically forms part of a co-ordinated development strategy that has many facets – improving the urban fabric of a city, increasing the supply of business premises, improving broadband connectivity, increasing housing availability and increasing work force skills as well as transport. Changing the attractiveness of an area is usually an expectation of such a co-ordinated strategy. Furthermore a co-ordinated strategy is necessary to maximise the economic growth potential of new transport investment (Bannister and Berechman, 2000; Vickerman, 2015). This combination poses a number of practical and empirical challenges for transport appraisal.

Conceptually a cost benefit analysis focuses on the primary market and surpluses in secondary markets are only considered if prices diverge from marginal costs in these markets. For investments that are co-ordinated across multiple sectors this approach becomes intractable due to the presence of multiple primary markets. Basing the appraisal on only one primary market (e.g. using changes in transport costs and quantities) is clearly inappropriate and can lead to significant errors including of the wrong sign (Neuberger, 1971; Simmonds and Bates, 2001; Geurs et al., 2010). A multi-market analysis with changes in welfare measured at the household level is one solution to this problem – for instance using spatial computable general equilibrium (S-CGE) models (Bröcker, 2010) or land use transport interaction (LUTI) models (Martinez and Araya, 2000; Simmonds, 2012). The modelling techniques needed though remain on the research frontier. This is unfortunate given that most major infrastructure projects are associated with significant changes in land use plans. An alternative to a multi-market approach is to look at the land market and measure the changes in surpluses that

occur there. However, the land market is an imperfect place to measure investments (see Arnott and Stiglitz, 1981 and Mohring, 1993 for a discussion vis a vis transport investments) and the use of land value uplift is fraught with difficulties associated with addressing displacement effects and netting out the land value uplift from construction costs and the effects of speculation. There also remains the question as to how accurate changes in land value are at reflecting transport investment benefits.

Transport induced land use change discussed in section 2.4 is distinct from multi-sectoral investments by the public sector. Changes in the land market induced by the transport shock are indirect effects. The primary market for the appraisal therefore remains the transport market, and price and quantity changes in the land market are general equilibrium effects which can be excluded from the appraisal aside from in the circumstances set out in section 2.4. With a well functioning land market user-benefits calculated under conditions of variable land use¹⁴ give an accurate measure of economic value. If land use change is associated with a change in attractiveness due to increasing varieties becoming available then an externality may be present. A number of methods have been proposed to measure these benefits/costs: the measurement of a land use externality in spatial interaction model within a maximum entropy framework (Martinez and Araya, 2000); the use of hierarchical logit models and the logsum within a Land-Use Transport Interaction (LUTI) model framework (Geurs et al., 2006); the disaggregation of the transport utility function between a transport cost term and an attractiveness term (Bates et al., 2006); and the calculation of economic benefit at the household level in a LUTI model (Simmonds, 2012).

From a practical perspective unfortunately these methods are relatively untested and remain on the research frontier. There therefore exists a question regarding the size of the error associated with excluding changes in varieties/attractiveness from the transport appraisal analysis. As discussed in section 2.4 drawing from evidence in other contexts suggests a wider benefit mark-up of 10-20%. There are limited transport examples that shed light on this. Drawing from Borjesson et al. (2015 table 4) we can also see that attractiveness benefits are context specific. The attractiveness benefit brought about by a road scheme whose impacts are quite dispersed is low at 0.5% of consumer surplus, but for a commuter rail link where attractiveness changes around stations are high the benefit is higher at 6%. An alternative to excluding changes in attractiveness/varieties from the appraisal is to hold land uses fixed. This approach has been adopted by the UK Department for Transport for example (DfT, 2014b). The problem with this approach is that the congestion and other

¹⁴ Fixed land use is when land uses in the Do Minimum and Do Something do not vary, whilst variable land use is when land use varies between the Do Minimum and Do Something

external costs associated with the traffic associated with the induced land use change are not included in the appraisal. Borjesson et al.'s analysis indicates that these costs are an order of magnitude bigger than the attractiveness benefits/costs at between 1% for the road scheme and 19% of user-benefits for the rail scheme. The implication is that whilst there is a need to develop analytical methods to capture the benefits from induced land use change it is better to base an appraisal on variable land uses (and exclude benefits from changes in attractiveness/varieties) than to calculate user-benefits based on fixed land uses. This does not however remove the need for further research on this matter.

3.3 Predicting quantity effects

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 economic impacts. These predicted changes have always formed part of the political debate that surrounds transport infrastructure but they are inevitably subject to considerable uncertainty. The larger the project and the longer the time-scale over which it is expected to have effects, the more variables need to be treated as endogenous and hence, inevitably, the greater the degree of uncertainty.

A range of modelling approaches is now available,¹⁵ making different assumptions about the economy – primarily in the treatment of the supply side. Many LUTI models are highly constrained and re-distribute existing employment to new locations. On the other hand, Multi- Regional Input – Output (MRIO) methods have an unconstrained supply side and output and employment can expand without any constraints on labour supply. Another important difference is the treatment of capital both human and physical. D’Costa et al. (2012) distinguish between people based productivity effects and place based productivity effects. The difference between the two is that people based productivity effects account for structural change in the economy – that is human capital (education, skills) and the industrial mix change in response to the transport scheme. Modelling people based productivity effects clearly treats the supply side in a more relaxed way than modelling only place based productivity effects. Some transport economy modelling captures people based effects without explicitly modelling the causal channels (e.g. using people based agglomeration elasticities – for an application see KPMG, 2014), whilst others model the causal channels more explicitly such as recursive or quasi-dynamic LUTI models and systems dynamic models¹⁶. A similar relaxation of

¹⁵ See Wegener (2011) for an overview of transport-economy modelling approaches.

¹⁶ See Wegener (2014) for a review of LUTI models

supply side constraints on physical capital can occur in a model with for example capital flowing from one region to another, or alternatively shifts in physical capital and land uses that permit cities or regions to specialise in response to reductions in transport costs. Even within a model genre it is possible to take adopt different approaches to the supply side – for example the treatment of labour supply within a Spatial Computable General Equilibrium model may vary with the application. These human and physical capital changes that generate structural change are long run effects taking 10s if not more than 100 years to occur in full (Barro and Sala-i-Martin, 2004 p59) and Broucker et al. (2004 p175) argue the difference between whether the model is predicting short run effects (with factors fixed) or long run effects can be a major source of difference between models. It is therefore important to not only distinguish between how constrained the supply side is within the modelling exercise but also the time interval over which the expected economy impacts will occur – the two things are obviously interrelated.

Having a family of models is valuable providing there is clarity about the differences between them and appropriate models are chosen for appraising particular types of project. Transparency is needed, particularly in two respects. First, the assumptions that drive predicted quantity changes need to be laid out clearly. And second, assumptions underpinning the valuation of these changes – and hence the impacts of the project on measures of economic performance (be it welfare or GDP) – need to be made clear. Lack of understanding of why different models are likely to produce different predictions means that inappropriate techniques may be used to appraise particular projects. Project promoters will systematically prefer some techniques to others, and lack of transparency means that effective challenge from the transport planning sector is difficult. Informed debate is then very difficult, as is evident for example from the debates surrounding the modelling of the economy impacts of the high speed rail line from London to the north (HS2) and the economic impacts of Heathrow and Gatwick Airports (Overman, 2013; Laird and Stroombergen, 2015).

Transparency in model structure needs to be accompanied by better benchmarking and auditing of transport-economy modelling studies. The aggregate studies of the role of transport infrastructure on economic performance in the tradition of Aschauer (1989, 1990) and summarised in a meta-study of Melo et al. (2013), whilst lacking the context specificity to be used in a modelling environment are useful as a reality check. They can be used to set bounds against which estimates of effects of particular projects should be compared. The econometric literature on ex post evaluation of the

effects of transport improvements faces many methodological challenges, but is another source of reality check for modelling studies.¹⁷

The uncertainty in the economy modelling means there is a role for sensitivity and scenario testing. One aspect of this is with respect to the way in which the supply side of the economy has been modelled and the possible private sector response to a transport project. Another is with respect to the 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. Policy making needs to recognise the potential synergies arising from interaction between policies, and techniques developed for assessing the full impact of transport projects need to be applied to complete policy packages. Thus, a series of small interventions may collectively – if not individually – create a wider economic impact. Scenarios can be produced of the effects of different combinations of policy and other changes, and each scenario can be value. Fundamentally, if each element of a policy package is necessary for change, and no one of them independently sufficient, then the package has to be evaluated as a whole.

4 CONCLUDING REMARKS

Transport investments are likely to have impacts (positive and negative) over and above conventionally measured user-benefits. These impacts may be social, environmental, or economic. They need to be taken into account in decision-taking and this requires rigorous techniques for establishing effects and for estimating their full value to society. The focus in this paper is on economic impacts. In particular, transport can raise productivity by fostering intense economic interaction; this can occur in clusters within narrowly defined areas or more widely by linking areas; transport shapes the level and location of private investment, unlocking development and triggering large scale redevelopment of urban and other areas; and 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.

¹⁷ For a survey see Redding and Turner (2016).

This suggests a modular approach. 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, so taking into account the possibility of relocation and displacement of economic activity. 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 a large 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. Notwithstanding that there remains a need to refine the evidence that exists so that it is more useful for transport appraisal. Such research is relevant not just for appraising transport projects, but for appraisal of policy change more broadly.

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