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Move to More/Less Productive Jobs

Final Report

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MOVE TO MORE/LESS PRODUCTIVE JOBS

Report to the Department for Transport

Final

20th February 2020

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EXECUTIVE SUMMARY

MOVE TO MORE OR LESS PRODUCTIVE JOBS

Move to more or less productive jobs (M2MLPJ) is concerned with the relocation of economic activity from one region to another and its effect on productivity and economic welfare. In addition to M2MLPJ, relocation of economic activity may also have distributive and other economic impacts such as reducing unemployment. M2MLPJ represents a displacement of economic activity – that is one region gains at another's expense. It was first identified as being relevant to transport appraisal in Tony Venables' paper for the DfT, later published in the Journal of Transport Economics and Policy in 2007 (Venables, 2007). If productivity varies between locations then displacement of economic activity has ramifications for the overall productivity of the economy. Including M2MLPJ in the appraisal of transport projects can therefore be significant if there is both a significant displacement of economic activity between regions and there exist significant productivity differences between the regions affected. For example, M2MLPJ formed the largest component of the wider economic impact benefits for Crossrail (Department for Transport, 2005 p9). Despite this relevance to appraisal there has been little research on M2MLPJ aside from the Dargay et al. (2008) research that estimated productivity differentials across GB.

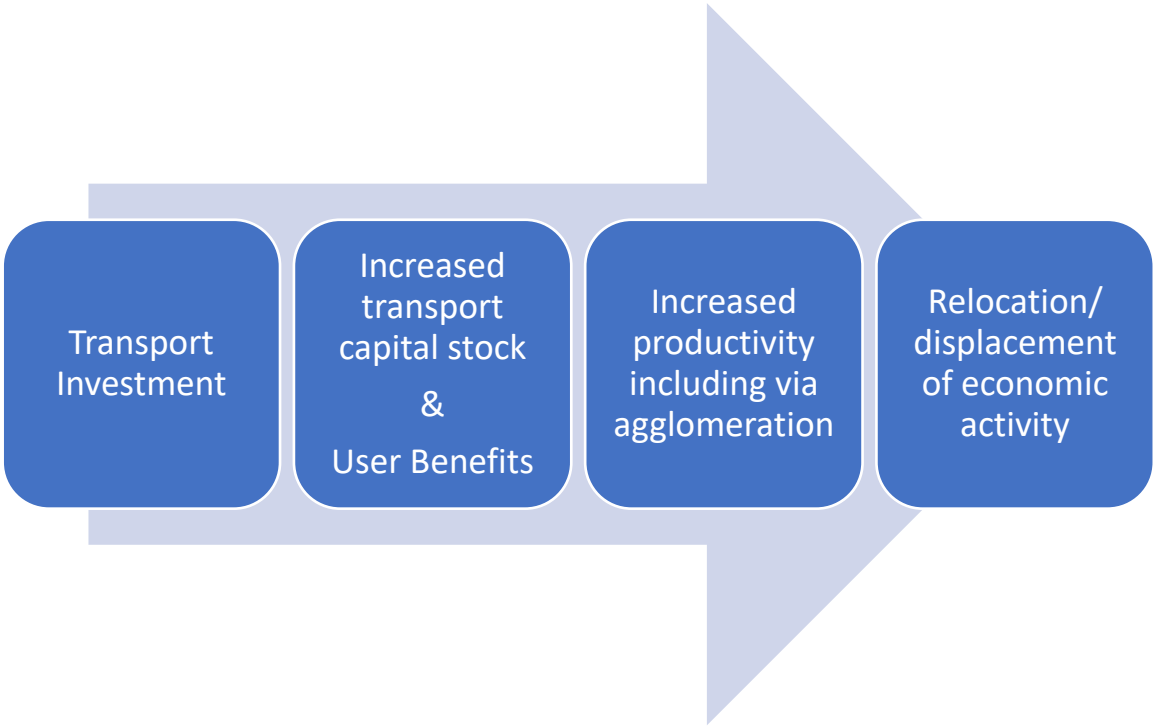
This paper therefore aims to fill that gap. It reviews the theoretical underpinnings to M2MLPJ, and any supporting evidence on the relocation of economic activity. We find there is both theoretical and empirical support for the concept of the displacing economic activity from one region to another as a consequence of transport investment (i.e. M2MLPJ). However, the evidence is less clear as to which of the micro-mechanisms that underpin M2MLPJ are the most important. The paper also re-examines the value of a re-located job, and the robustness of the parameters used in TAG. The paper concludes that the theory underpinning the M2MLPJ wider impacts in TAG is robust – that is a shift to a more productive location creates a positive wider impact, but a shift to a lower productivity location creates a negative wider impacts. However, it is considered that the mechanics of the TAG calculation need adjusting, both to utilise more up to date parameters but also to better reflect the nuances of M2MLPJ. Furthermore, the productivity differential parameters in TAG are now outdated and also need updating. A number of recommendations for the updating of TAG are therefore made.

A SPATIAL EQUILIBRIUM

Productivity differentials between places arise because of differences in: skill levels/ occupational mix, endowments, the stock of knowledge/ technology, agglomeration and market access. In equilibrium, mobile factors move to equate returns on capital, and to equate utility for households, and the resultant productivity differentials between regions then transfer into different prices for immobile factors. These price differentials are particularly obvious for land and housing, but also will occur for other immobile amenities. The spatial variation in the prices of immobile goods and in productivity give rise to a spatial equilibrium, in which no business or household can move location without either losing profits or utility/welfare.

TRANSPORT INVESTMENT, RE-LOCATION AND DISPLACEMENT – THEORY AND EVIDENCE

A transport investment changes this equilibrium by altering the productivity of a location. It does this by increasing the stock of capital (i.e. more transport infrastructure) in that location, and by increasing the inherent productivity of a location through a reduction in transport travel times and costs (seen in the appraisal as user benefits), as well as increasing productivity through increased agglomeration. These changes in productivity alter returns to capital and to labour, destabilising the equilibrium and leading to a displacement of economic activity from one location to another at the new equilibrium. This causal process is illustrated in Figure 0-1.



Note: Feedback loops excluded for clarity

FIGURE 0-1: THE RELATIONSHIP BETWEEN TRANSPORT INVESTMENT AND THE RELOCATION OF ECONOMIC ACTIVITY

Looking at this in more detail for firstly an intra-regional transport investment, and then for an inter-regional investment. An intra-regional transport investment (e.g. an urban rail project) increases productivity within a region, and in so doing attracts mobile activity to that region – displacing it from other regions. This is unambiguous. In contrast, an inter-regional transport investment (e.g. an inter-city rail connection that connects regions A and B), depending on context, can trigger a move from region A to B, or from B to A. The context is important. In a country such as the UK, with a mature transport network in which transport costs are already relatively low, an inter-regional transport investment could lead to a dispersion of economic activity form the core to the periphery. This would be the case for industries where the centrifugal forces to geographic concentration (specifically land rents and dis-economies of scale) outweigh the centripetal forces (market size effects, thick labour markets and pure external economies). The tension between the centripetal and centrifugal forces implies that there are variable returns to agglomeration. We would expect these to vary by industry. In practice the neat distinction between intra-regional and inter-regional

transport investments is unlikely to be seen in practice, with many transport projects serving both functions. For example, upgrades to the motorway network will benefit both inter-regional traffic and intra-regional traffic. This makes it hard to predict a priori where transport investment will displace economic activity from and to.

The displacement can occur through a variety of mechanisms. For firms there are three broad mechanisms: firms in the benefitting region can out compete rivals in other regions thereby capturing market share (this would include an increase in firm start-ups); firms re-locating between regions; and firms in different regions and industries competing for labour (the classic urban versus rural scenario). For households there are also three broad mechanisms: households may remain fixed in location with workers commuting between regions, or households may migrate between regions, or workers may enter/exit the labour market.

The empirical evidence shows significant positive productivity effects of transport investment, but these are now considered to be much smaller than the early studies (in the late 1980s and early 1990s) had suggested. Furthermore, there is evidence that more recent investments (e.g. in the 2000s) are giving returns smaller than those associated with earlier investments (e.g. in the 1950s and 1960s) – as the transport networks are now more developed. Econometric work in this area is challenging, and there is a lot of variation in the results between studies. Meta analyses of these studies indicates that the largest source of difference between studies is the econometric method used. It is therefore important to employ rigorous econometric methods in the analysis of the economic impact of transport projects, and when reporting the evidence to ensure only credible studies are cited.

The empirical evidence is clear that a key driver to productivity gains in the economy is through infrastructure use (i.e. user benefits). Who uses the transport investment is therefore critical to the productivity gains delivered. The primary beneficiaries therefore are the industries that use the infrastructure. As different industries demand different attributes from transport infrastructure, the productivity impacts of new infrastructure vary substantially by mode and industry (e.g. HSR benefits tradable services and tourism as does air, whilst roads benefit manufacturing). Importantly as there are international differences in how transport infrastructure is used, there are international differences in the sectoral productivity impacts that transport investment delivers (e.g. air and port infrastructure benefit the agricultural sector in economies that export agricultural products, but may benefit tradeable services (air) and manufacturing (ports) in countries which export services and manufactured goods).

The evidence further indicates that employment, firms, and population will move location in response to a transport investment. Cities are the main beneficiaries. Unconnected regions lose out. Displacement also leads to regional sectoral change (i.e. changes in specialisation) – as only certain industries gain from the transport investment.

We also see empirical support for theories pointing towards a centralisation of economic activity in response to transport investment. There is limited evidence for the dispersion effects of transport investment in mature economies, albeit there is evidence that in general manufacturing is dispersing in mature economies. This is an evidence gap. There is also evidence that households change

behaviour via a variety of different responses. However, it is difficult to pinpoint the magnitudes of the different responses, though commuting and population movement (migration) are likely the most important. This is because labour supply elasticities are relatively low. There is limited evidence on the behaviour of firms, but there is sufficient to know that firms do alter behaviour in response to transport investment. Evidence on the micro-behaviour of firms and households is also an evidence gap.

In summary economic theory and the empirical evidence strongly support the concept of a move to more or less productive jobs. Economic theory predicts that transport investment will displace activity from one place to another, and we see strong evidence of this displacement happening. The evidence is less clear when one tries to drill down to the different micro-mechanisms, and the identification as to which micro-mechanism is the most important.

THE VALUE OF RELOCATION/DISPLACEMENT OF ECONOMIC ACTIVITY

The value of a transport investment that moves economic activity from one region to another is fully captured within transport user benefits and the other associated elements of a transport cost benefit analysis (changes in producer and government surplus) providing there are no market failures. Where market failures occur, prices do not equal marginal social cost in all the secondary markets, and the full social value of a change in these markets is therefore only captured with an analysis of these markets. This is the standard theory that underpins the concept of wider impacts as applied in TAG.

In practice, however, the situation is complex as multiple market failures co-exist. The TAG approach is to treat each market failure in isolation and calculate its wider impact. TAG therefore identifies several market failures of relevance to transport appraisal, and gives guidance as to how to calculate the additional surpluses. It also identifies several market failures, which it does not provide guidance for. These include market failures in the land market, the labour market leading to structural unemployment, as well as mentioning corporation tax. The broader literature on wider impacts also refers to further market failures, for example knowledge spillovers (e.g. arising from foreign direct investment). This discussion is relevant to M2MLPJ as the nature of M2MLPJ – displacing economic activity from one location to another – means that more than one market failure might be relevant to the appraisal, and some of these may not have any TAG guidance.

Market failures of relevance to a project that displaces economic activity could, subject to context, include: the standard TAG ones of imperfect competition (income tax, static and dynamic clustering), as well as those associated with the land market, those giving rise to structural unemployment, those associated with knowledge spillovers (from inward investment), and any associated with corporation tax (if it impacts on investment rates). It is, however, important in the context of TAG to isolate the market failure of particular relevance to the behaviour under consideration. For M2MLPJ we are specifically concerned with the changes in location. Thus we are only interested in market failures that distort the decision as to where to locate. To examine this more closely we developed a model of household and business location choices. This model informs us that income tax on earnings distorts household location decisions, but corporation tax on businesses does not distort business location decisions. The implication is that income tax is the only market failure of relevance

to the choice of location (i.e. M2MLPJ). To account for this market failure in the cost benefit analysis it is necessary to add in the tax revenue received (or lost) from changes in income. This tax revenue would include any changes in earnings related taxes so would also include employees and employers' national insurance, as well as income tax. It would not include changes in tax receipts from other taxes, such as corporation tax or VAT. TAG therefore needs to be updated to reflect this.

The conclusion that only taxes on earnings are relevant to M2MLPJ, is not to say that M2MLPJ is not associated with other wider impacts from either other taxes or other market failures. In fact arguably it has a very close relationship with some of the other TAG wider impacts – particularly agglomeration and dynamic clustering, and the labour supply wider impact. Two points arise from this. Firstly, these wider impacts should be calculated as well as the M2MLPJ wider impact, and secondly consistency between the treatment of M2MLPJ and these wider impacts is needed in TAG. In addition M2MLPJ may also be associated with other non-TAG wider impacts. These may include investment (leading to knowledge spillovers), land market distortions, and structural unemployment. Such market failures and wider economic impacts can also be thought of as forming part of the re-balancing agenda. Within the context of the TAG framework though, these market failures should be treated separately from the M2MLPJ wider impact.

To summarise, we find that the underlying economic principles to TAG for valuing a change in the location of economic activity (i.e. M2MLPJ) is sound. However, the manner by which it is parameterised needs to be updated to reflect that only taxes on earnings are relevant to the M2MLPJ wider impact.

TAG PRODUCTIVITY DIFFERENTIALS

The TAG productivity differentials identify how the relative productivity of a local authority varies against the national average. The way they are applied in transport appraisal effectively gives the sum of the productivity differences, in GDP terms, between the regions from which the economic activity is displaced.

Consideration of the requirements of transport project appraisal in conjunction with the manner that productivity varies by agglomeration and regional endowments suggests that a higher level of disaggregation is desirable. With this in mind for like for like displacement (i.e. displacement within the same industry, but between different locations) the productivity differentials should ideally vary:

- By local authority district (LAD), and by industry. This is to reflect differences in agglomeration and endowments between LADs.
- By location within the LAD. This is because agglomeration impacts have a strong bearing on the productivity differentials and differing locations (city centre or suburbs), and city sizes affect the productivity gains due to agglomeration.
- By forecast year. This is to reflect changes in background demographics, which feed into changes in productivity due to agglomeration.

Where there is a move between regions and between industrial sectors there is a further requirement to have the ability to understand how productivity varies when an industry contracts in one region, whilst a different industry expands in another region.

Following the discussion regarding the value of M2MLPJ, the productivity differentials also need to represent variations in labour productivity, and not total factor productivity.

Much like the empirical work understanding transport investment's impact on the economy, it is econometrically challenging to obtain robust productivity differentials. The empirical study of how productivity varies spatially remains an active research area. Recent contributions have highlighted the need to separately identify the impact of skills from local effects, identify variable rates of return to agglomeration, separate out the static and dynamic components of agglomeration and successfully address any endogeneity problems.

The field has moved on substantially since the Dargay et al. (2008) study which is the source of the TAG productivity differentials. As a result of this improvement in knowledge, our view is that the productivity differentials in TAG are weak by today's standards. This is because: the estimation method did not effectively control for individual skills; it included an adjustment to the wage for regional price variations rather than using nominal wages; three years of data from the same workers was pooled without adjusting the standard errors; and it did not control for endogeneity.

In our view it would be very challenging to estimate a new robust set of productivity differentials that are sufficiently disaggregated to meet the requirements of project appraisal. Our suggestion would be to use a model to predict the productivity differentials at the desired level of disaggregation. This model could either be an existing model or a new model estimated specifically for the purpose. The two key sources of spatial variations in productivity are regional endowments and agglomeration, with agglomeration expected to be the main driver of the spatial differences. For this reason any model adopted would need to have a robust estimation of variations in labour productivity with agglomeration.

The advantage with using an existing model, such as that used to give the agglomeration elasticities, is achieving consistency across different parts of TAG. The disadvantage would be that an existing model may be focused on total factor productivity differentials and not labour productivity differentials (as are required here), may not be sufficiently disaggregated and may not capture any differences in productivity due to endowments. An estimation of a new model would be more resource intensive and would carry with it risks of not being able to recover any robust parameters. It would also mean that there would not be consistency between the agglomeration parameters in TAG and the M2MLPJ parameters. The advantage of a new model estimation though would be that it could be specifically targeted at the requirements of M2MLPJ.

SUMMARY, RECOMMENDATIONS AND FURTHER RESEARCH

Broadly speaking our conclusions re-affirmed that a move to more or less productive jobs will lead to a wider impact if productivity differences exist between localities and these interact with market failures. This wider impact specifically relates to a distortion caused by income taxation in the

decision as to where to locate and is a function of productivity differences. There may be other market failures that become relevant when jobs re-locate, but these are not directly related to the choice of location nor are directly productivity related. Subject to context, they could include: the standard TAG ones of imperfect competition (income tax, static and dynamic clustering), as well as those associated with the land market, those giving rise to structural unemployment, those associated with knowledge spillovers (from inward investment), and any associated with corporation tax (if it impacts on investment rates).

Where there is a shift to a more productive job this will generate a positive M2MLPJ wider impact, but where there is a shift to a lower productive job this will lead to a negative M2MLPJ wider impact. This is not to say that there will not be net positive wider impacts from re-balancing the economy, it is just that the M2MLPJ wider impact will be negative if economic activity is displaced to a lower productivity region. This is consistent with TAG. However, it is essential that the estimates of changes in employment and population in affected localities are full long-run changes, taking into account adjustment in the local labour market (e.g. changes in employment in existing local firms) and, where appropriate, changes in the housing stock associated with movement of workers.

Our review of TAG would suggest that the manner that M2MLPJ is implemented in TAG needs to be re-visited and updated. The existing productivity differentials are getting dated, methods have moved on, and are not sufficiently disaggregate enough to capture the nuances of M2MLPJ. Additionally, M2MLPJ is closely related to a number of other wider impacts and the inter-relationship between these also needs to be reviewed. We have separated the recommendations into short (within a year), and medium term (within five years) options.

Short term

1. Update the current differentials in TAG to be percentage differences, so they are consistent with the TAG equations. The current values in the wider impacts dataset are sourced from the coefficients (β) of the regression model. To convert these to percentage differences the following transformation should be applied to them: $e^{\beta}-1$.
2. Update equations in TAG to be in terms of wages and not GDP. This will require additional research/reviews to:
    a. Update the marginal tax parameter τ_1 to relate to earnings only.
    b. Consider the role as to whether TAG should give guidance on how to predict GDP change from M2MLPJ. If so, additional research may need to be commissioned to advise on this.
3. Ensure TAG is clear that M2MLPJ is only relevant when there is displacement in employment from one region to another, with no net change in employment at the UK level. Changes in specialisation which lead to employment shifts between industries in a region do not generate an M2MLPJ wider impact.

Medium Term

4. Commission research to develop new productivity differential parameters for TAG based on either the transfer of an existing econometric model or the development of a new model. There are pros and cons to each alternative.
5. Review the inter-relationship between M2MLPJ wider impact and the wider impacts of (a) labour supply, (b) dynamic clustering and (c) agglomeration in TAG to ensure consistency in treatment across the wider impacts. There is a strong inter-relationship between these wider impacts: changes in labour supply are one of the mechanisms by which M2MLPJ can come about, M2MLPJ is the source of dynamic clustering, whilst the productivity impacts due to agglomeration are the primary source of the productivity differentials in M2MLPJ. Ideally some parameters should be common, or come from the same source, across these wider impacts, to ensure consistency.
6. M2MLPJ is concerned with changes in land use. Due to difficulties in calculating user benefits when land uses change, arising from amongst other things measuring changes in zonal attractiveness, it is currently difficult to obtain a complete measure of total economic impact when M2MLPJ is applicable. Addressing this knowledge gap is therefore important for such projects.
7. There is an evidence gap in the empirical evidence that supports M2MLPJ. In particular there appears to be little evidence on the role transport investment may have in dispersing economic activity from the core to the periphery, as would be predicted by new economic geography models. There is also little on the micro-behaviour of firms that do 'move', and with respect to households the evidence is not sufficiently detailed to be able to quantify the proportion of re-located jobs that is taken by inter-regional commuters, increases in local labour supply or workers who have migrated between regions. Address these evidence gaps are an area of future research, and would be useful in understanding the expected scale of any M2MLPJ.
8. Wider impacts other than those mentioned earlier may also be relevant for projects where M2MLPJ wider impacts are calculated. These may for example include unemployment impacts, or impacts associated with re-balancing the economy. The wider impacts for which guidance is produced should be reviewed, with consideration given as to whether the range should be broadened. This may then lead to the commissioning of longer term research projects to parameterise any 'new' wider impacts.

1 INTRODUCTION

1.1 Background

The policy context to this research is the government's re-balancing agenda. This includes major investment in transport projects that are aimed at facilitating the regional growth outside of London. Such projects include the Road Investment Strategy (RIS), HS2, Northern Powerhouse Rail and East-West Rail amongst others. A key part of the analysis supporting these schemes is how to bring the impacts of re-balancing into the appraisal. This research is concerned with re-visiting one aspect of this – that is the move to more/less productive jobs (M2MLPJ). This is currently detailed in TAG Unit A2.3.

The expected increase in economic performance of the regions, as a result of these transport projects, will be driven in part by pure growth, but in part will also stem from displacement from places such as London, or other regional locations. Productivity will vary between the areas from which and to which the economic activity is displaced. London and the south east have higher levels of productivity than elsewhere. Given these varying levels of productivity it therefore becomes important to be sure that the appraisal properly captures all the benefits of increased economic performance in the regions, once displacement effects have been taken into account. A key aspect of this analysis is the M2MLPJ.

1.2 Research Objectives

This project is aimed at understanding the theoretical reasons why investment in lower productivity regions will lead to displacement of economic activity from higher productivity locations to the targeted region, whether this is supported by empirical evidence, but also whether the treatment within TAG of this regional growth is correct. Specifically:

- Give clarity on the drivers for the M2MLPJ, where the move involves a shift to a lower productivity area.
- Identify the value of output created in a lower productivity region, from a firm or worker previously located/working in a higher productivity locality
- Review TAG in relation to the guidance for M2MLPJ particularly:
    - The rationale for output per worker being valued lower in areas with low productivity even though the market price of the good is common across all areas.
    - The robustness of the productivity differential data contained in TAG.

1.3 The existing modelling and appraisal framework

M2MLPJ was identified as being relevant to transport appraisal in Tony Venables paper for the DfT, later published in the Journal of Transport Economics and Policy in 2007 (Venables, 2007). This paper also importantly addressed the matter of agglomeration. TAG guidance in Unit A2.3 is aligned with this in that a re-location of jobs to/from, for example, a more productive city centre location

will, in the presence of an income tax, create a wider impact (WI). The income tax is the market failure that creates the additionality to user benefits. Originally within TAG the framework within which this sits is that of one in which household location remains fixed. A change in commuting costs triggers a change in job – to a more/less productive job. This is a private decision on the part of the worker, but given the presence of the income tax results in a WI. In the post-TIEP version of wider impacts part of TAG (May 2018) the fixed household location is relaxed, and the guidance now better reflects Tony Venable's 2007 paper.

If the number of jobs remain fixed in each zone in the Do Minimum and Do Something counterfactuals then all M2MLPJ WI gains/losses will net out to zero. For there to be a net gain/loss from the M2MLPJ there also needs to be a change in job location. These changes in job location also give rise to dynamic clustering. The classic example is Crossrail where the alleviation of a commuting constraint on Central London permits employment growth in Central London (with employment displaced from London suburbs). To analyse M2MLPJ a model of job re-location is therefore needed. The TAG guidance therefore stipulates that a land use transport interaction (LUTI) model, or some equivalent modelling framework, should be used to model how jobs move between locations.

Within the wider impacts dataset a set of productivity differentials are set out. These productivity differentials were estimated to represent how productivity per worker varies between different locations. They are presented at Local Authority District level. These differentials were estimated using data from the Annual Survey of Hours and Employment (ASHE) and it was intended that they control for all observable differences between workers. That is the productivity differentials reflect inherent place based productivity differences. It is our understanding that these productivity differentials are rarely used in practice – even where displacement effects have been calculated. It would be useful to gain any insights from DfT why this is the case.

An important economic mechanism closely related to M2MLPJ, mentioned above and set out in TAG, is dynamic clustering. Net gains (or losses) from M2MLPJ cannot occur without dynamic clustering simultaneously occurring. Analytically this is shown in Venables (2007). Dynamic clustering occurs when there is a change to the level or location of economic activity as a result of a transport investment. Agglomeration forces, from the changes in the level or location of economic activity, lead to a change in the productivity of all workers within the locality. If displacement effects form part of these land use changes, then dis-agglomeration effects will also be felt. The net productivity effect is the sum of the agglomeration and dis-agglomeration effects. This inter-relationship between dynamic clustering and M2MLPJ effects is very important when calculating WIs, and arguably is not particularly well elaborated in TAG.

1.4 Report Structure

Following this introductory section, Chapter 2 sets out the theory that informs us that the capital of the transport investment and the user benefits are the drivers to changes in productivity. These productivity changes then lead to a spatial changes in the economy. In Chapter 3 we present the results of a rapid evidence review setting out how transport investments have changed the economy, firstly focusing on changes in productivity and then on the displacement of economic activity. We also cover the limited evidence that exists on the behaviour of firms and households. In

Chapter 4 we consider the second research objective regarding what the value of a job is that moves locations. In the fifth chapter we benchmark TAG guidance on M2MLPJ against these theoretical and evidence led positions, and identify some areas where some refinement might be necessary. We explore two of these in detail in Chapters 6 and 7. Specifically in Chapter 6 we examine the use of GDP in the M2MLPJ calculation, which addresses the third objective of this research, whilst in Chapter 7 we consider the robustness of the existing TAG productivity differentials. In the final Chapter we present a brief summary against the four research objectives and make some suggestions for further research.

2 ECONOMIC THEORY ON RE-LOCATION DUE TO TRANSPORT INVESTMENT

In this section we consider the first research objective concerning the drivers to the Move to More or Less Productive Jobs. We therefore examine the economic theory regarding why firms, workers and households might re-locate as a result of transport investments. In the first sub-section we discuss the sources of variations in productivity, and then in the second sub-section we describe how we can have variations in productivity in an economy in equilibrium. In the third sub-section we look at how transport investment will alter that spatial pattern. The user benefits from a transport investment primarily, but also increases in capital stock, act as the driver to increase productivity. This increase in productivity then de-stabilises the equilibrium giving rise to a movement of economic activity between locations. The direction in which economic activity (e.g. to the core or to the periphery) moves is determined by background economic conditions.

2.1 Sources of variations in productivity

An examination of productivity differences in an economy would find that it varies across the country. However, a simple neo-classical approach to regional economics would take the position that labour and capital will 'migrate' between regions until the marginal rates of return on real income and capital are equal. In such a case there would be no spatial variation in productivity. In reality this does not happen. This is because there are regional differences in factor endowments, some factors are immobile, there are differences in skill levels/occupational mix, agglomeration economies exist, there are differences in the stock of knowledge/technology and differences between regions in terms of market access.

Different regions have different factor endowments; sunshine and water are essential for agriculture and different regions have different quantities of both. Some industries exploit the environment for tourism or for production (e.g. quarrying, mining or oil production), and obviously environmental conditions differ between regions. Such factors are obviously immobile, but immobility also exists in other factors. For example, labour is not perfectly mobile; young, skilled and highly educated workers are more mobile than other workers. Family ties can be an important influence that restricts mobility too.

Agglomeration economies are an additional source of difference between regions. It is widely recognised that the clustering of economic activities 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 supported by a substantial research literature that quantifies the positive relationship between economic density and productivity (see for example Rosenthal and Strange (2004), Melo et al. (2009), Combes and Gobillon (2015)). The agglomeration economies that give rise to these productivity benefits occur through a series of microeconomic mechanisms categorised as sharing, matching and learning (Duranton and Puga, 2004). We therefore find that the most productive places *ceteris paribus* are located in the largest cities.

Agglomeration economies plus some immobility of labour and other factors are the sources of some of the reasons we find differences in skill levels and occupational mix between regions, but also differences in the stock of knowledge / technology. Mobile workers tend to migrate to the more productive locations, usually the largest cities, thus giving rise to differences in skill levels between regions. We also find that the largest agglomerations tend to accumulate the most knowledge, giving rise to differences in knowledge/technology between regions. Finally, Specialisation will occur in the industry or industries of comparative advantage, giving rise to different industrial and occupational mixes between regions.

Within a spatial economy transport is essential, connecting firms with firms and households with firms. Transport therefore gives firms market access. Firms with the greatest market access will be more productive than others, as for a given cif price[1] they can drive further to deliver a product (*ceteris paribus*). Transport costs are also a source of imperfect competition, as they allow a degree of spatial monopoly power to exist when firms experience internal economies of scale.

2.2 A spatial equilibrium

Businesses and households (if mobile) locate to maximise welfare. For businesses this is profit related, and is therefore a balance between factor prices (land, labour, other inputs), productivity of the location, and the transport costs needed to serve the market. For households it is more complex. For them welfare maximisation is a balance between maximising income (the wage) and maximising quality of living: the latter being a function of the costs of living (including house prices) and the amenities on offer. With respect to the latter some households may prefer to locate in cities due to the social benefits they offer in terms of access to say, leisure facilities. Other households may derive welfare from the natural environment and their location choice may reflect that. Households are quite heterogenous.

To reach equilibrium, mobile factors will therefore move between areas to equalise the returns between regions on capital for businesses, and utility (welfare) for households. In equilibrium no business can therefore move location without reducing profit. Furthermore, in equilibrium no household could move location without losing welfare. At equilibrium businesses and households will be located in both high productivity locations and in low productivity locations. In equilibrium the regional productivity differences will translate into different prices of immobile factors, particularly land and housing. Differences in amenities will also be reflected in prices. Low productivity places therefore have low nominal wages, but also a low cost of living as house prices adjust until returns to mobile factors (real income of households) are equalised across places.

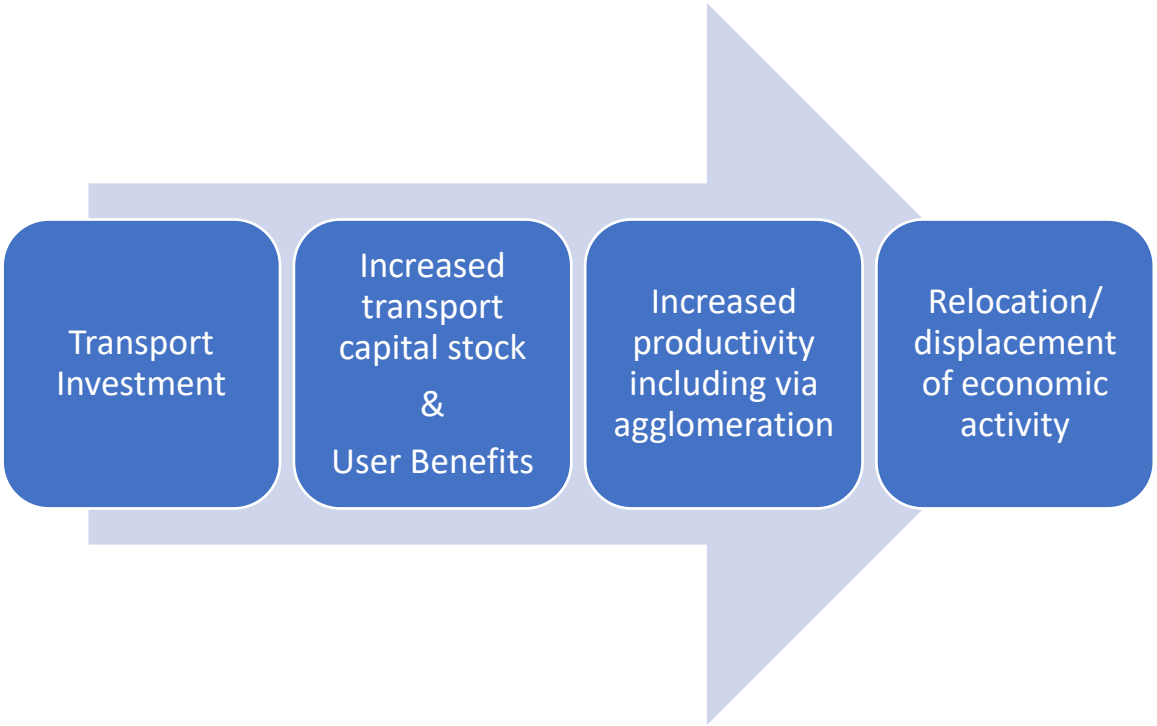
We can therefore see that a perfectly functioning economy does not have equal productivity in all regions.

[1] Cif price is the cost insurance and freight price.

2.3 Transport investment, regional productivity and displacement

2.3.1 Overview

A change in any of the contributing factors that affect business performance (productivity, factor costs or transport costs) will destabilise the spatial equilibrium and initiate businesses to move location[2]. Similarly, a change in any of the factors that affect household welfare/utility such as a change in incomes (through e.g. a regional labour productivity increase) or a change in regional quality of living (including housing an commuting costs) could instigate a move. A transport investment is a shock that can initiate that change. This is illustrated in summary form in Figure 2-1.



Note: Feedback loops excluded for clarity

FIGURE 2-1: THE RELATIONSHIP BETWEEN TRANSPORT INVESTMENT AND THE RELOCATION OF ECONOMIC ACTIVITY

A transport investment (the first box in Figure 2-1), in say a region with low productivity, will, through increased transport capital stock and user benefits (the second box) improve the locational

[2] As workers can commute between regions it is not necessary for households to move location if employment locations move.

efficiency of the region. These are the drivers to an increase in productivity, which pushes the production function outwards (the third box).[3]

The increase in productivity destabilises the spatial equilibrium, leading to a re-distribution of economic activity (the fourth box). The higher productivity around the transport investment initiates a flow of mobile factors towards the region to take advantage of the higher returns post-transport investment. This may improve productivity further through increased agglomeration and generate further cumulative causation effects and associated inwards investment. At the new equilibrium there will be more economic activity in the low productivity region if this is the one that benefits from the transport improvement, (marginally) higher productivity, nominal wages and house rents. For an inter-regional transport investment two outcomes are possible: economic activity may shift to the lower productivity region (the periphery), or it may shift to the higher productivity region (the core). Which outcome prevails depends on the underlying economic conditions. With both outcomes regional productivity in both the core and periphery increases, as do nominal wages and house rents.

This is process is as applicable to an investment in a low productivity region as it is to an investment in a high productivity region.

2.3.2 Transport investment and the production function

In our discussion as to what the drivers are for businesses to relocate, as illustrated in Figure 2-1, we split the discussion into how a transport investment can increase productivity, and then how those changes in productivity then trigger the relocation in economic activity. This section is concerned with how a transport investment will change productivity, and how the drivers to that are user benefits and an increase in transport capital stock.

Classical approaches to understanding economic growth, whilst ultimately insufficient to give us a full understanding of the role of transport in growing a regional economy, are very enlightening as they describe some of the key building blocks which more complete theories utilise. The starting point invariably is an economy wide or regional economy production function, which relates output (Q), to inputs of labour (L) and capital (K). Here capital includes both private and public capital – the latter of which includes transport infrastructure.

$$Q = f(L, K) \quad (1)$$

A neo-classical production function has the following properties:

[3] A transport investment could also initiate a move of households between locations, if it changes the quality of living in an area in some way (e.g. removes the nuisance costs of road traffic and improves safety). Here though we focus on its impact on productivity, and with respect to households, on the change in real income received by households as a consequence of the change in productivity. In effect we are assuming that the only change in household quality of living arising from the transport investment arises through channel of changes in earnings.

- Constant returns to scale (a doubling of inputs doubles output)
- Positive and diminishing returns to all inputs. Therefore, for example, as stock of capital in the economy increases the return on 'new' capital diminishes, though is always positive;
- Marginal product of capital (labour) approaches infinity as labour (capital) tends to zero; and
- Capital and labour are essential.

A Cobb-Douglas production function as in Equation (2) meets these requirements. In (2) α represents the output elasticity of labour.

$$Q = AL^{\alpha}K^{1-\alpha} \quad (2)$$

This simple model offers us a number of insights. Firstly, as the stock of transport infrastructure and other transport related capital (e.g. rolling stock, vehicles, etc.) increases, the marginal increase in economic output diminishes. Thus we would expect the rate of return on transport investment to be lowest in regions with large amounts of transport stock, and highest for countries with poor transport networks. Secondly, if transport investment increases the level of service offered by a transport system – in terms of travel times, reliability and comfort – and these improved levels of service increase productivity then transport investment can also affect economic output through the efficiency term, *A*, in Equation (2). This occurs as improved transport levels of service can improve productivity by either reducing the time spent by workers travelling during business hours, or alternatively by increasing the productivity of the time they spend travelling when on business[4]. Related to this are the productivity effects of agglomeration economies. Through improvements in the micro-economic mechanisms between firms and workers of matching, sharing and learning, there can be gains in productivity from pure proximity arising for reasons other than the direct benefits of a better transport service. These agglomeration benefits are also seen as acting through the efficiency term, *A*, in Equation (2).

The third insight offered by this model is that if a transport investment can increase labour supply, that is the number of people willing to work at a given wage, then economic output will also increase – albeit at a diminishing rate. As commuting costs act as a deterrent to enter the labour market for the marginal worker, then a transport investment that lowers commuting costs can increase labour supply. This is one of the wider impact mechanisms detailed in TAG. Here the transport investment is acting through the *L* term in in Equation (3).

The production function forms an intrinsic part of the Solow-Swann model of regional economic growth. In essence, with households saving a fixed proportion of their income from which investments in capital are financed, the level of capital in an economy will increase up until the point that the depreciation on existing capital equals the amount invested. At this point productivity growth in the economy ceases and the economy will only grow at the rate the population grows. This model is deficient in a number of ways, and has therefore had numerous extensions.[5] A key extension is the treatment of human capital, through the use of a labour augmenting technology.

[4] For example, the more comfortable conditions of first class on a train may permit more work to be undertaken during the journey than travelling in standard class.

[5] See Abreu (2014) for a summary review of neo-classical growth models.

This technology is external to the model. With such a labour augmenting technology growth at the steady state per capita will be determined this augmenting technology (at say a rate *x*).

In this extended model transport investment affects regional growth through the production function. By changing the efficiency of the local economy (the *A* term) this gives an immediate increase in productivity, by shifting the production function outwards. This is shown in Figure 2-2 with the vertical jump at time t_1 in the output per worker. The outward shift in the production function means that the economy will strive to achieve a higher steady state. This steady state is achieved through increased investment in capital over time up until the point that the depreciation of existing capital equals the amount that is invested per year. In Figure 2-2 this happens at time t_1*. At this point growth returns to the long run rate of growth, *x*, which is the rate of technological change.

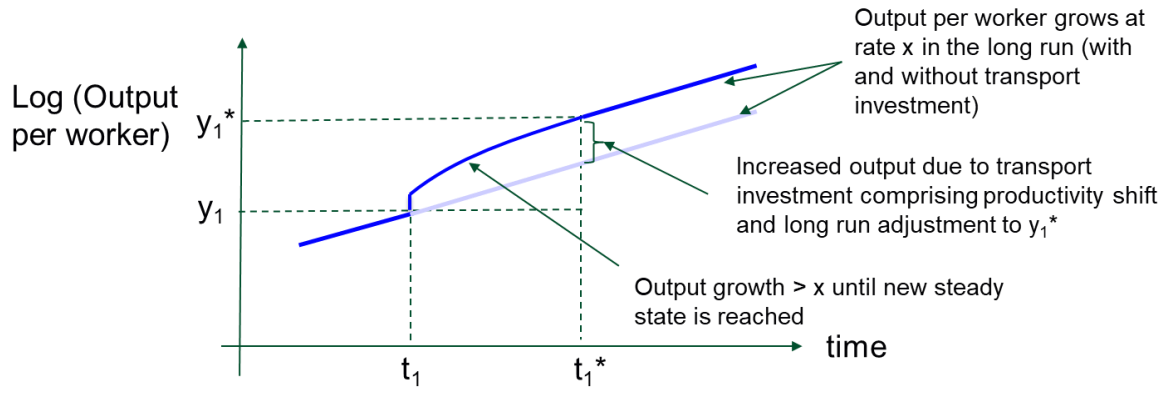


FIGURE 2-2: SOLOW-SWANN MODEL OF THE IMPACT OF TRANSPORT INFRASTRUCTURE INVESTMENT

An important implication of this model is that transport infrastructure investment gives a one off shift in productivity. This is because at time t_1* growth returns to the long run rate of growth. The second important implication is that the productivity growth occurs in two stages: an immediate jump in productivity followed by a gradual, but diminishing, rate of growth. Over this period of time growth exceeds the long run rate of growth in the economy (here depicted by the rate *x*). Empirically it has been found that the rate of convergence of economies to their steady state is slow – in the order of several generations – and we would expect the adjustment post transport investment to be of a similar timeframe.

From our perspective, which is that of understanding the drivers to a Move to More or Less Productive Jobs, the key implication of this model is that the transport investment affects the A term (locational efficiency) and the K term (capital stock) in the production function and by doing so drives productivity upwards. It does by improving transport services (i.e. user benefits) and by increasing the amount of capital in the economy. Transport investment also affects productivity via agglomeration economies which in this framework forms part of the A term (locational efficiency).

2.3.3 Economic growth and displacement

In this section we present how the changes in productivity brought about by the transport investment give rise to a spatial re-distribution of economic activity. These are the third and fourth boxes in Figure 2-1, and completes the discussion on the drivers to a Move to More or Less Productive Jobs. In presenting this we need to draw on endogenous growth and new economic geography theories, which are therefore introduced. We also split the discussion between intra-city/intra-regional investments and inter-city/regional transport investments. This is because they have different implications for the displacement of economic activity.

An introduction to Endogenous Growth and New Economic Geography

A key critique of neo-classical growth theories is their inability to adequately explain, within the model, why disparities remain between regions and countries. Long run growth in developed economies has been sustained over many decades, and developing economies have not 'caught up'. Within countries, some regions 'lag' behind. Theories on endogenous growth and the field of New Economic Geography offer insights here, and give a more nuanced view as to the role of transport investment in boosting economic performance.

Endogenous growth emphasises the role of human capital as a source of long run economic growth through the creation and diffusion of knowledge. Education, research and development and new ways of working, both within business and as a consequence of the institutional setting, all form mechanisms by which long run growth can occur.

New Economic Geography (NEG) links agglomeration economies, internal economies of scale and transport costs as sources of imperfect competition. This imperfect competition then permits the spatial variation in economic performance between regions that neo-classical models cannot predict. NEG emphasises that there exist centripetal forces that will centralise economic activity (market size effects, thick markets and knowledge spillovers and other pure external economies), and centrifugal forces that will disperse economic activity (immobile factors, land rents, congestion and other pure diseconomies) – see Table 2-1. A policy shock, such as a transport investment, will then disturb the existing balance and the relative strengths of the different centripetal and centrifugal economic forces will determine whether mobile economic activity will centralise or disperse.

Table 2-1: Forces affecting geographical concentration

Centripetal forces	Centrifugal forces
Market size effects (linkages)	Immobile factors
Thick labour markets	Land rents
Pure external economies	Pure external diseconomies

Source: Krugman (1998)

Below we set out the implications of this on economic performance in the context of an intra-regional (or urban) transport investment and an inter-regional (or inter-city) transport investment.

Intra-city transport investment: economic growth and displacement

As mentioned earlier there are external benefits to clustering – agglomeration economies. An intra-city transport investment would be expected to raise city productivity, by the mechanisms outlined earlier, and in so doing will displace economic activity to the city. This will raise city productivity further, and in so doing will induce a circular-and-cumulative causation process that continues to displace economic activity to the city until a new equilibrium is reached.

This is illustrated in Venables (2007) for the case of the monocentric urban model – where all employment is located in the Central Business District (CBD). In equilibrium all households are neutral to their location in the city (distance from the CBD) as lower land rents exactly compensate for higher commuting costs. Lot sizes are uniform throughout the city. At the edge of the city land rents are zero (equivalent to land rents outside the city). City size is therefore determined by commuting costs.

An urban transport investment that reduces commuting costs therefore raises land rents throughout the city. This results in a discontinuity between land rents on the edge of the city and those outside the city. The city therefore expands until once again at the edge of the city rents are zero – with commuting costs exactly compensating for land rent differentials. In the expanded city with lower transport costs there will be an increase in productivity arising through agglomeration[6].

The key point here is that the urban transport investment has initiated a displacement of households and workers to the city. In this model the workers migrate from outside the city. The way the model is presented it is suggestive of a shift of households from rural to urban. With productivity of urban workers being higher than that of rural workers this is therefore seen as a Move to More Productive Jobs.

Conceptually, however, households and workers could move from other cities and those cities may be bigger or smaller than the recipient city. This is because the economy is in equilibrium prior to the transport investment. In that equilibrium no household or worker can move location without making themselves worse off. The urban transport improvement de-stabilises this equilibrium, and households and workers can now exploit the productivity shock in the city to increase their real income. Thus if different cities have different productivity levels (e.g. via agglomeration economies), it could be the case that workers migrate to the recipient city from large cities and small cities, as well as from rural areas. Thus the displacement effect that occurs as a result of the city expansion may be a Move to a Less Productive Job, as much as being a move to a More Productive Job.

A point that is often forgotten in these discussions is that the benefits of agglomeration are dependent on the relative strengths of the centripetal and centrifugal forces to geographic concentration. The tension between the two implies that there are variable returns to

[6] The increase in economic density is driven both by lower transport costs, but also by an increase in city size - dynamic clustering (in the TAG terminology).

agglomeration. Furthermore we would expect these to vary by industry – as different industries demand different amount of land or skilled workers say. For the UK Graham (2007b) finds five broad sectors (out of nine)[7] are subject to diminishing returns to agglomeration. These are transport, storage and communication; distribution, hotels and catering; manufacturing; IT; and construction. Firms from sectors that experience diminishing returns to agglomeration will be more likely to move from a large conurbation (which would be associated with high productivity) than a firm from a sector that experiences constant returns to agglomeration.

Another relevant feature that is worth drawing out is that the displacement of employment does not have to be to a like for like job. Clearly if agricultural workers are moving to a city – as in the Venables model – the job they do in the city is likely to differ from the one they previously undertook.

Inter-regional transport investment: economic growth and displacement

Possibly the largest contribution of New Economic Geography to understanding the economic impact of transport investment is with respect to inter-regional or inter-city transport investment. If economic activity is mobile then the choice of which region to locate production can be shown to vary with inter-regional transport costs. With high transport costs production will occur in every region; with medium transport costs production will centralise to those with the largest markets, and with low transport costs production will disperse to regions with low factor costs. That is as transport costs fall, spatial inequalities between regions increase, but as they continue to fall this trend will reverse and spatial inequalities between regions start to diminish. This is the bell shaped curve of New Economic Geography.

Krugman (1991) illustrated this process with a simple two region model. In this model there are two regions: the core and the periphery. The core is larger than the periphery, whilst the periphery has lower factor costs (land rents, wages, etc.). There are no transport costs within a region, but there are transport costs between the regions. Firms also benefit from internal economies of scale in production. Populating this model with some hypothetical data (see **Table 2-2**) ,Krugman shows that with high transport costs firms will locate a factory in both regions and there will be no trade between regions. This is because total costs of production of a single large factory in the Core is 13 units (=10+3), a single large factory in the periphery is 16 units (=8+8), whilst having two smaller factories one in each region is lowest at 12 (=12+0). With medium shipping costs it becomes cost effective to close one factory and expand output at the other factory. The factory at which production centralises is located in the largest home market to minimise transport costs – which is the Core in this scenario. Under medium shipping costs total costs of production in the Core is 11.5 units. That is a lowering of transport costs leads to a trade between regions and a centralisation of economic activity to the largest regions. A further reduction in inter-regional transport costs will eventually lead to production locating in the regions with lowest factor costs – which in this model is

[7] Those exhibiting constant returns to scale were real estate, banking, finance and insurance, business services and public services.

the Periphery. Here with low shipping costs the total costs of production in the Periphery is 8 units (=8+0).

Table 2-2: Economies of scale exist in production (either internal or external)

Production in	Production costs	High shipping costs	Medium shipping costs	Low shipping costs
Core	10	3	1.5	0
Periphery	8	8	4	0
Both	12	0	0	0

Source: Krugman (1991)

Re-organisation effects (i.e. displacement) at a regional level in response to the transport cost reductions are therefore substantial, and in this hypothetical example dwarf the productivity gains. The key contribution relative to the neo-classical model is that economic activity may locate to either end of the inter-regional transport link depending on the existing level of development in the country. Arguably therefore investment in inter-regional transport links in developed countries with mature transport networks and relatively low transport costs will lead to a dispersion of economic activity. This is the expected situation for the UK, though it is dependent on the relative sizes of the push and pull factors (centripetal and centrifugal forces in Table 2-1) for each industry.

From our perspective the salient point that can be drawn out is that inter-city or inter-regional transport investment in a developed economy with a mature transport network like ours may lead to some industries re-locating from the more productive 'core' of the country to the less productive 'periphery'. In doing so businesses are using a more transport intensive means of production – that is they use more transport inputs in the production process. Therefore we expect the transport investment to increase the amount of freight tonne-kms and business person-kms travelled, as production re-locates to the periphery.

Venables (2017) develops the urban city model, discussed above, for a two city context that allows for the consideration of inter-city transport investments. Additionally, he allows for there to be two tasks, which can be produced in each city, and the pattern of specialisation – which tasks are produced where – depends on city-task productivity and the level of inter-city trade costs. Following Ricardian principles cities increase their specialisation in the task in which they hold comparative advantage. If one or both of these tasks are subject to localisation agglomeration economies then productivity will increase further, and a range of possible situations may occur in terms of the final sizes of the cities – including extreme cases where one city captures all of a task, and the other city shrinks significantly in size. Localisation agglomeration economies are the benefits from being located proximate to similar firms/workers, whilst urbanisation agglomeration economies are the benefits from locating proximate to pure economic mass.

Firm behaviour and the dynamics of firm re-location

We can envisage a number of different behaviours by firms associated with a M2MLPJ. These can be categorised into three broad types:

WITHIN-INDUSTRIES

1. Within the same industry with re-location of the firm from Region B (origin) to Region A (destination). Region A will then export to Region B;
2. Within the same industry, but with firms in Region A (destination) outcompeting firms in Region B (origin). Firms in region A will therefore expand production, taking market share from firms in Region B. Region A will therefore export to Region B. This mechanism may also occur through an increase in firm start-ups in Region A (the destination).

BETWEEN-INDUSTRIES

3. Between industries. Industry A in Region A (destination) expand at the expense of Industry B in Region B (origin). Here workers shift between industries as the relative fortunes of the different industries change. This is the rural/urban model used by Venables (2007), where rural workers in rural industries move to the city in response to an urban transport investment. The direction can also work the other way, as investment in rural areas would benefit rural industries, and workers may move from the city to rural areas in response.

In terms of the dynamics the competition mechanisms (2) and (3) above would imply a gradual – over time – shift in economic activity between regions. The destination region firms get stronger and stronger each year attracting more workers (between industries in mechanism 3) or taking more market share from rivals (within industries in mechanism 2).

With respect to firm re-location (mechanism 1), some firms may completely shift location in a single time period thereby 'jumping' between regions. This may be, for example, because they have outgrown their existing premises, or alternatively find that their existing premises are no longer as fit for purpose as they used to be. These are the marginal businesses vis a vis location. In the Do Something counterfactual the transport investment alters the productivity differential between the different regions and one or some of these marginal businesses may consider moving to the destination region, rather than moving to an alternative premises in the origin region. Such businesses will not only need to find premises, but will also need to recruit a new workforce. The latter may prove challenging, particularly if labour markets are tight. Furthermore, if businesses have a certain amount of fixed capital tied up in the original location, then this might act as a friction or cost to the move. This may mean that only certain types of businesses may 'jump' to a new location – those who have little fixed capital tied up and those for whom workforce skills are less relevant to the production process. Alternatively, firms may only 'jump' a short distance (e.g. to a neighbouring region), thereby being able to retain some or most of their workforce who will now commute further. The latter is akin to the Crossrail case where businesses were expected to concentrate in central London at the expense of firms in outer London, with households remaining in location. These 'small' jumps would also be strongly inter-related with the household mechanism of increasing commuting, which is discussed below.

For other firms a more gradual re-location is likely as firms invest in production facilities in a new location and wind down operations in the original location. Operations can be wound down over

time by not investing further in the origin region, thereby letting capital there depreciate. See for example Bröcker (2014 pp. 864-868) for an introduction to dynamic models of factor migration.

In the context of a transport appraisal we compare two counterfactuals – the Do Minimum and the Do Something – at different forecast years. With dynamic factor mobility, whilst it is valid to compare different land use patterns between the counterfactuals for a specific forecast year, it is also important to realise that these differences will have built up over years, starting from the point at which the transport investment was introduced into the Do Something counterfactual. We would only expect some business activities to jump between locations – and possibly these will only be between neighbouring regions – for others the process will be much more gradual.

Household behaviour

The above discussion has been very much couched in terms of businesses moving location in response to changes in productivity. In equilibrium there is however a simultaneity between household and business decision-making. This is because business re-location requires a change in labour supply in the regions affected. This change in labour supply is explicit in the equilibrium of the theoretical models Venables sets out (Venables 2007 &2017). These changes in labour supply can be serviced by households in three obvious ways:

- **Commuting.** If businesses move between regions, then households may choose to commute to the region where the job is now located, rather than move regions or change in employment. It is the higher wages (productivity) that is available in the recipient region that will attract inter-regional commuters. This is because with perfectly competitive labour markets an alternative job would be available in their region if their job moved to a different region. This is akin to the Crossrail arguments with jobs re-locating to Central London local authority districts, but households remaining in the district they currently reside in. Clearly such commuting behaviour can only occur if the business re-location occurs over a 'commutable' distance (e.g. within London as in the Crossrail example).
- **Migration.** Some households will migrate to the region benefitting from the transport improvement. Again this will be to take advantage of higher wages post-investment that are now available in the recipient region, as with competitive regional labour markets alternative employment could be found locally if their job moved regions.
- **Entering/dropping out the labour market.** An increase in wages (labour productivity) in the region that receives the transport investment will encourage some of the region's economically inactive residents to enter that regional labour market. If the change in employment in the origin region (where the job has moved from) is small relative to the size of the labour market then workers whose job has moved will be able to find alternative employment. If, however, the regional employment change is large wages will adjust (downwards) and marginal workers will drop out of the labour market. That is there will be a contraction in the amount of labour supplied by households in the origin labour market.

In reality, we would expect all these mechanisms to act simultaneously. Context is also likely to be important, as markets may not always be perfectly competitive. For example, frictions in the regional housing markets (e.g. arising from credit constraints) may reduce migration and encourage long distance commuting, or imperfectly competitive labour markets (for certain demographics) may reduce alternative job options in the origin region, thereby leading to longer distance commuting or migration to a new region. The commuting/migration decision is also contingent on household structure with households with multiple workers and/or children likely to experience the largest frictions to migration.

3 RAPID EVIDENCE REVIEW

In this evidence review we are primarily interested in empirical evidence on the drivers to a Move to More or Less Productive Jobs. We therefore in the first instance focus on the productivity impacts of transport, before looking at how transport investment displaces economic activity. Finally, we identify that not all transport investments will have an impact on the economy, as a number of underlying pre-conditions may not be present.

3.1 Causal Identification

In looking for evidence on the impact of transport investment on the economy there is a need to ensure that a suitable causal identification strategy has been employed in the studies being cited. This is because we see correlations between output, productivity, transport stock and transport investment in both time series and cross-sectional data. Unfortunately, there are very few ex post studies that employ rigorous analytical methods. For example, in their 2015 review of the empirical literature on the impact of transport investment and policy, What Works (2015) found only about 1% of all the policy evaluations and evidence reviews met their minimum standards. In this rapid evidence review we focus on those studies as well as a number of rigorous studies that have since been published. We do refer, in places, to some older pioneering studies due to their importance in the literature, even though these studies do not always meet the What Works standards.

3.2 Transport investment and productivity

As discussed earlier a key driver to the Move to More or Less Productive Jobs is that transport investment gives rise to user benefits which increase the efficiency of being located in a place. Firms benefiting from the transport investment would therefore be expected to see an increase in productivity, which shifts the production function outwards – as per the discussions in §2.3.2. As the first part of this review we therefore look for evidence of productivity changes as a result of transport investment.

Early empirical studies sought to explain the impact of public sector investments, including transport, on aggregate economic output. These typically used Cobb Douglas production functions based on aggregate or regional state level data (as per Equation (2)). A key study was that by Aschauer (1989) who used a US dataset of aggregate capital stock and total factor productivity. Whilst the elasticities he found are universally considered to be too high, his work led to a large empirical literature which ,from a transport perspective, has now been subject to two meta-analyses by Melo et al. (2013) and Holmgren and Merkel (2017). Melo et al. find an average output elasticity of 0.06 to changes in transport capital stock. That is if the transport capital stock changes by 10%, economic output would increase by approximately 0.6%. Melo et al.'s average elasticity of 0.06 whilst substantially less than the pioneering estimates is likely to be an overestimate for current investment programmes in the UK. This is because it not only includes studies that constructed whole networks, such as the US Inter-State highway network where network wise step changes in

accessibility were delivered, but also includes the early studies which did not employ particularly robust empirical strategies and found large elasticities (Holmgren and Merkel, 2017). Jiwattanakulpaisarn et al. (2012) looking at recent US data for example conclude that the marginal productivity gains from further expansions of the US road network are positive but trivial. There is therefore substantial evidence that transport investment has, on average, improved total factor productivity at a country or regional level – albeit in developed countries with mature transport networks the gains from further expansions are much smaller than historically.

The aggregate approach adopted in these studies however disguises the much more nuanced manner in which transport investment affects productivity. The first point is that with the driver to productivity primarily being user benefits we would expect that industries that use the transport system will be the ones who will get the largest productivity increase. This expectation is supported by the empirical literature. Fernald (1999) for example finds that the most vehicle intensive industries received the largest productivity increases from the construction of the Inter-State Highway network. Duranton et al. (2014) again using US data find that cities with larger amounts of highways specialise in manufacturing, whilst Lin (2017) looking at the case of China finds that tourism and industries with cognitive and non-repetitive tasks benefitted the most from high speed rail investment. Lin argues these industries require face-to-face meetings – and therefore are the beneficiaries of the HSR improvement. In contrast Lin finds that highway improvements benefit non-service sector industries (e.g. manufacturing), which is consistent with highways expansion having a larger impact on trade costs than HSR. It is also found that the service sector tends to be the largest beneficiary from airport investment (Brueckner, 2003, Percoco, 2010, Sheard, 2014).[8] Again the service sector tends to use the new transport services (in this case the airport) more than other industries. In what seems to counter this viewpoint Gibbons and Wu (2017) find significant impacts on Chinese manufacturing firms, but not in the service sector from the market access provided by airports. One explanation for this is a combination of the fact that manufacturing firms need supply chain connectivity and links the ability for sales personnel to travel, and in China manufacturing is a high growth sector.

Studies using micro-data on firms also find productivity improvements from transport improvements, although there are very few such studies. Of particular relevance to this commission is a study of the impacts of UK trunk road and motorway additions on firm performance. In this work Gibbons et al. (2019) find significant productivity effects on existing firms (with increases in output per worker and wages) as a result of re-organisation, and also find an increase in the level of employment and number of firms within the area. The largest employment effects are found in producer services, transport (specifically road freight and cargo handling) and in 'other' industries which is a residual category. They consider that a plausible interpretation is that new transport infrastructure attracts transport intensive establishments to an area, and also leads to some

[8] It should be noted that some of these studies (Brueckner, 2003, Duranton et al., 2014, Lin, 2017, Percoco, 2010, Sheard, 2014) look at employment changes and not productivity per se. However, we would expect that industries that receive productivity gains in a particular location to expand output, and therefore employment. The channels via which this can happen are increased specialisation within the city/region, and/or through the industries in this region capturing market share and displacing activity in this industry to the recipient region.

reorganization of production in existing businesses. It again emphasises that the driver to the productivity and other economy changes are the user benefits delivered by the transport project.

Another study using firm level data is that by Holl (2016) who looks at Spanish manufacturing firms and the impact of the motorway network expansion on their productivity. She finds that the motorways have a positive impact on manufacturing firms' productivity. This arises through two sources: firstly the direct benefits from the improvements to the transport system, and secondly because of the changes in land use (economic activity moves to locations served by the motorways). Here again the driver to the productivity change are the user benefits, but in addition agglomeration benefits are also a driver – as discussed in the previous section. She also finds that the productivity gains firms experience are heterogenous: traditional manufacturing industries with low value-weight ratios in inputs and outputs gain more than other types of manufacturing. These stand out sectors in her analysis are: drinks, textile and clothing, the printing industry, and the other manufacturing and recycling sectors. This again emphasises that the productivity gain is largest for those industries that use the transport system the most.

3.3 Transport Investment and Displacement

The earlier economic theory section of this report (Section 2) drew out that transport investment changes firm level and labour productivity, which then initiates a move in economic activity. Simple neo-classical theories suggest that activity will move towards the area which experiences the productivity shock, whilst theories on agglomeration additionally emphasise the cumulative-causation effects within urban areas can lead to further growth in urban centres as a result of a transport investment. New Economic Geography theories identify that economic activity can either move from the periphery to the core or vice versa. There are three key channels by which economic activity in a region can increase: existing firms can expand production, new firms can start-up in the regional economy, or firms re-locate form a different region. In the previous sub-section we examined evidence on the initial drivers to the move (that of the effect of the transport investment via user benefits on productivity). In this section we now consider the evidence on transport investment and displacement.

The first point to note when considering this evidence is that very few studies have actually analysed displacement. They typically analyse the level of activity in different localities, from which interpretations are drawn. The pioneering study of Rephann and Isserman (1994) is one such study. They identified that urban areas and their adjacent counties were the largest beneficiaries of the construction of the US interstate highway network. They considered that rural counties along the interstate highway network gained little aside from in retail activity – and speculated that this was due to commuters and retirees locating in these counties. They find that counties that are not direct beneficiaries of the interstate network and not in an urban fringe, experience many negative effects. They interpret this as implying that displacement occurs between rural counties that are not connected to the inter-state highway network and a combination of those that are plus urban areas and their fringes. Chandra and Thompson (2000) takes this one stage further and show that the interstate highway network did displace economic activity from rural counties that were not connected to the network to rural counties that were connected to the network. This shift in economic activity is associated with increases in wages, which in itself is associated with a shift to

economic activity with higher levels of productivity (namely manufacturing). This is one of the few studies that has explicitly accounted for displacement.

Duranton and Turner (2012) also extend Rephann and Isserman's analysis by looking at the impact of interstate highways within the city itself, finding that a 10% increase in a city's initial stock of highways causes about a 1.5% increase in city employment over a twenty year period. This employment is taken to be displaced. Within the city itself increased road provision has been found to increase the level of suburbanisation (or spread) of the city in both the US (Baum-Snow, 2007a) and China (Baum-Snow et al., 2017). Thus we can see that road provision affects both micro-choices within a city, and more macro choices such as location choices between cities. In a very recent study Baum-Snow et al. (In Press.) in looking at the impact of the construction of the Chinese highway network find that economic activity is displaced to 'primate' regional cities from the hinterland including the hinterland cities. For example they identify that a 10% increase in roads within 450 km of a prefecture city reduces non-primate prefecture population by 1.7%, but increases primate prefecture population by 1.1%.

These city growth effects of inter-regional transport infrastructure are not just limited to highways, as both HSR and airports can be associated with displacement. For example, in China, Qin (2017) finds that HSR lines have a negative impact on the counties that they pass through, with activity displaced to the cities which form the nodes of the HSR network. Lin (2017) finds an HSR connection increases city employment by 7% with the tourism sector and industries which require workers with skills in cognitive and non-repetitive tasks growing the most. With respect to airports and air connectivity we see increases in city employment (Brueckner, 2003, Gibbons and Wu, 2017, Sheard, 2014) and population (Tveter, 2017).

This general finding across these studies that activity concentrates to cities, and within that to the primate cities in the context of a rapidly industrialising China or the performance of US cities as a consequence of the construction of the interstate highway network, is consistent with the New Economic Geography predictions on displacement from periphery to core, as set out in §2.3.3. In terms of dispersion of economic activity from the core to periphery, as we might expect in developed economies with mature transport networks, there is less evidence. There exists general evidence that manufacturing has dispersed in the US, Australia and Europe, but linking this dispersal to transport investment remains a gap in the literature. There does exist some qualitative work by Cheng et al. (2015) that suggests HSR in France has dispersed some service sector activity away from the core (Paris) to cities on the HSR network.

The displacement of economic activity from one location to another by a transport scheme can also have a profound impact on the industrial composition of the local/regional economy. Displacement and increased specialisation all can lead to changes in industrial composition. The evidence reviewed above indicates that transport investment favours economic activity that utilises that mode of transport thus investments in air (Brueckner, 2003, Percoco, 2010, Sheard, 2014)and HSR (Cheng et al., 2015, Ahlfeldt and Feddersen, 2017, Lin, 2017) tend to favour service sector activity, and highways tend to favour manufacturing (Chandra and Thompson, 2000, Duranton et al., 2014, Baum-Snow et al., In Press.). The areas from which activity is displaced not only have a reduced economic performance, but can also be left specialising in low value added industries such as retail

or agriculture (Rephann and Isserman, 1994, Chandra and Thompson, 2000, Baum-Snow et al., In Press.) or can experience other negative impacts such as a reduction in productivity (Holl, 2016)[9] or a reduction in new firm start-ups (Holl, 2004).

In summary therefore in the empirical literature we find support for the theory that firms will respond to a productivity shock by moving location. In the main cities are the beneficiaries, with regions that do not receive the productivity gain often losing out. The manner that different modes of transport favour different industries when combined with displacement of economic activity also means that transport investment is often associated with changes in industrial composition, with highways favouring logistic operations and tradeable sectors, and air and HSR tradeable services and tourism. There is limited evidence on the dispersion of economic activity to peripheral locations as a consequence of a transport improvement and on the nature of the firms that re-locate. Another weakness of the empirical data, particularly from our perspective, is that the empirical work has a distinct US and China angle and is also very much associated with the construction of a new network – neither of which is directly relevant to the current UK policy context.

3.4 Firm behaviour

With respect to firm behaviour we have identified three mechanisms out competing rivals and capturing market share including new firms start-ups; firms re-locating; and firms in different industries competing for labour. The analysis that underpins such evidence requires firm level micro data which only Holl (2016) and Gibbons et al. (2019) have utilised.

Holl (2016) examines how highway investment effects firm re-location and productivity. In her data on Spanish manufacturing firms 90% of firm re-locations are local, and on average they move the firm closer to the motorway network. This is consistent with a view that a firm may seek new premises, possibly on development sites made available by the new road links, whilst wishing to retain their labour force and local supply chain. With respect to productivity, she finds that firms that re-locate into highway corridors typically have higher productivity compared to the incumbent firms already in the highway corridor, if locating into a CBD highway corridor or a suburban highway corridor. However, given the low number of re-locating firms she therefore concludes productivity growth created by the highway scheme within its vicinity has to be driven by the incumbent firms.

Gibbons et al. (2019) for UK highway investments find that local employment increases are driven by new firms operating within the area of interest. They imply that these new firms are displacing activity from elsewhere, but do not distinguish whether the firms have re-located or are start-ups which displace activity from incumbents (wherever they are located).

[9] A possible mechanism for this is a reduction in agglomeration productivity gains if economic density reduces.

Clearly these two studies are insufficient to draw out any generalisations, and the field requires much more empirical work.

3.5 Household Behaviour

In Chapter 2 we identified three main household responses associated with M2MLPJ: commuting, migration and entering or exiting the labour market. There is evidence for all these aspects of behaviour occurring as a result of a transport investment. That is we see evidence of increased commuting in response to transport investments that reduce the cost of travel, there is evidence that population increases as a consequence of transport investments – which is evidence of migration/displacement; and there is evidence that labour supply increases in the vicinity of transport investments. We highlight a few of the studies here. It should be noted however that the majority of this evidence does not identify the underlying mechanisms e.g. for increased commuting and therefore can arise for reasons other than M2MLPJ.

Commuting

There is a large body of transport evidence on travel demand and its response to changes in travel time and price (see for example reviews and meta-analysis in De Jong and Gunn (2001), Goodwin et al. (2004), Graham and Glaister (2004), Holmgren (2007), Litman (2019)). The Department itself issues guidance on demand in the TAG note on Variable Demand Modelling where fuel price and public transport fare elasticities are presented. Other industry standards such as the *Passenger Demand Forecasting Handbook* for rail, and the 2004 TRL report *The Demand for Public Transport: A Practical Guide* also contain advice on demand elasticities.

Of course commuting to a job that has moved is only one of the mechanisms that give rise to a change in commuting demand. Others would include an increase in labour supply, and a change in residential location. We are not aware of any evidence that separately distinguishes between these different mechanisms, nor are we are of any evidence that specifically refers to changes in commuting distance as a consequence of employment re-location (with the same firm).

Having said that, commuting as a mechanism in M2MLPJ is likely to be most relevant in metropolitan areas where jobs may move between the centre and the suburbs – this is the Crossrail argument. For such environments there is strong evidence that increases in the stock of transport infrastructure increase travel in general and commuting distances specifically (Baum-Snow, 2010, Duranton and Turner, 2011). Their research implies unitary elasticities – a 1% increase in transport stock increasing travel by 1%[10]. It is also worth noting that Holl (2016) finds that 90% of firm re-locations are local, which might suggest that changes in commuting behaviour could well be the most significant household response when the employer re-locates.

[10] Their research is likely to be context dependent as it is based on US cities which have high levels of car dependency and congestion.

Migration

As we do not expect transport investments to alter birth and death rates, beyond changes in the number of traffic and travel fatalities, we interpret changes in population from transport investments as evidence of migration. Population changes can occur at the intra-regional level (e.g. moving house within a city) and at the inter-regional level, with inter-regional migration probably most relevant to our interest in M2MLPJ impacts.

Several of the studies already referred to provide evidence of population changes at an inter-regional level. Baum-Snow et al. (In Press.) identify that a 10% increase in roads within 450 km of a prefecture city reduces non-primate prefecture population by 1.7%, but increases primate prefecture population by 1.1%, whilst Tveter (2017) found that the Norwegian policy to use (new) air services to support a dispersed population in the late 1960s and early 1970s increased population and employment at municipalities receiving an airport by 1% per annum between 1970 and 1980 (the period analysed) – though these municipalities are small (<7,700 residents). Additionally investment in Wisconsin (in the US) between 1980 and 1990 in air services and highways had a positive impacts on rural population levels, though no discernible impact at the urban level (Chi, 2012).

At a more micro-level (intra-regional or intra-city) we also find population movement between locations. For example, in the US and China there is strong evidence that increased transport stock in cities has led to an increase in population in the suburbs and a contraction in city centres (Baum-Snow, 2007a, Baum-Snow et al., 2017). A UK study of populations along rail commuter routes in West Yorkshire found populations had increased by 8% against control areas due to the opening of new stations (Blainey and Preston, 2010). It is hard to interpret these changes in local population levels as sorting type effects where employment location remains unchanged, or migratory (when employment location moves as well). The Baum-Snow work finds that employment locations have also moved – so potentially can be seen as a M2MLPJ response by households. The West Yorkshire rail study on the other hand could just be households taking advantage of a new commuter opportunity to an existing place of employment, as was found in an ex post survey of new users of improved commuter routes in the Inverness area (DHC, 2008) (see also the earlier discussion regarding changes in commute distance in response to a transport investment).

Labour supply changes

In looking for evidence of changes in labour supply we draw on a small number of studies where changes in employment are examined at a household level with controls for population change. By controlling for population the increase in employment arises from an increase in the number of household workers in employment – i.e. an increase in labour supply. Broadly speaking these studies find employment accessibility elasticities of between 0.02 and 0.04 (Berechman and Paaswell, 2001, Johnson et al., 2017, Ozbay et al., 2006). That is a 10% accessibility improvement increases employment by between 0.2% and 0.4% - which in this context is delivered by an increase in labour supply.

Some more recent unpublished work using different in difference methods on three UK rail and tram schemes in Laird et al. (2017) found results of similar order of magnitude, albeit they are not directly comparable:

- Stirling-Alloa new rail line: a 10% reduction in access distance led to a 0.27% increase in employment
- Manchester Metrolink Phase 1 no impacts, Phase 2 7.7% increase within vicinity of station. Note there was complementary land investment in Phase 2, and this finding will be confounded with that investment.
- Robin Hood Line: a 10% reduction in station distance gives a 0.07% increase in employment

We therefore can see that there are small changes in employment due to changes in labour supply in the vicinity of public transport schemes. As some of this employment will be displacing output from elsewhere. We are not aware of similar studies on highway schemes.

Summary

The above review of household behavioural responses to transport investment highlights the difficulty in pinpointing the magnitude of the M2MLPJ household mechanisms. A multitude of responses are at play that drive changes in commuting behaviour, household location and inter-regional migration decisions, only some of which can be attributed to M2MLPJ. It is clear from this limited review though that households do change behaviour, but beyond that it is hard to quantify the M2MLPJ specific responses. It therefore remains unclear what proportion of re-located jobs are taken by inter-regional commuters, increases in local labour supply or workers who have migrated between regions. In all likelihood the proportions will vary according to context – with commuting effects dominating in large metropolitan areas like London, and migration effects dominating for longer distance re-locations of economic activity. Given the reasonably well functioning nature of the UK labour market in the majority of regions, it is unlikely that labour supply effects will dominate the other two household responses. However, these are opinions and empirical research in this area is needed.

3.6 Transport-Economy Frictions

The preceding discussions have painted a picture in which transport investment creates a productivity shock which then feeds through the economy creating growth and leading to a new spatial equilibrium. There are however examples of many transport projects have had a limited impact on the economy: for example the San Francisco BART (Banister and Berechman, 2003 pp283-285), the Sheffield Supertram (Dabinett et al., 1999.) the early lines of the Manchester Metrolink (Forrest et al., 1996), and the Tyne and Wear Metro (Davoudi et al., 1993) and its extension to Sunderland (Du and Mulley, 2007) where limited or muted impacts have been found.

The consensus view is that in a developed country, a mature transport network transport is a complement to more important factors of economic growth - the most important of which is an available workforce, others being a supportive institutional framework and the availability of finance

and a willingness to invest (Banister and Berechman, 2001). If these conditions are not present then it is quite possible that the economic impact of transport investment will be very limited.

This is a cautionary note as transport's ability to stimulate the economies of lagging regions or countries will be limited if they there are structural weaknesses present in those regions/countries. In the case of the San Francisco BART and the Sheffield Supertram institutional failings were relevant. For the Tyne and Wear metro a lack of "strong complementary planning policies" supportive policies (Davoudi et al., 1993) is given as a reason for the lack of impact, whilst a mixture of weak underlying economic conditions and low levels of user benefits have been cited for the initial Manchester Metrolink lines (Forrest et al., 1996). There is limited empirical work in this area that actually quantifies the relevance of these 'pre-conditions'. However, a recent study by Crescenzi et al. (2016) identified that economic returns to transport investment were weakest for regions with weak government institutions, thus providing further support to this 'pre-conditions' viewpoint.

The reason that some studies identify no significant ex post impact from a transport improvement could be methodological, rather than arising because of being a poor transport project (Banister and Berechman, 2003 pp253-254). For example, Rietveld and Bruinisma (1998) find that the A1 motorway in the Netherlands had no noticeable regional impact, but concluded that the aggregate data used at a regional level may disguise some of the impacts. Graham et al. (2013) find no impacts of the Madrid-Barcelona high speed line on output growth of Spanish provinces, using a similar aggregate level of impact. The more disaggregate firm level analysis employed by Holl (2016) and Gibbons et al. (2019) might therefore be necessary to identify the impacts of transport improvements in regions with mature transport networks.

4 THE VALUE OF MOVING TO A DIFFERENT REGION

In this section we address the second research objective concerned with the value of a job that 'moves'. The starting point for this is the transport cost benefit analysis literature, which we support with a mathematical model of a two region economy with taxation. We then broaden the discussion to consider other market failures and their associated Wider Impacts should be considered in the context of a Move to a More or Less Productive Jobs.

4.1 Wider impacts in TAG

The framework in which we consider the value of a moving a job (or household) from one region to another is that of cost benefit analysis. If there are no market imperfections then, even if there are productivity differences between the regions, the job/household moves between regions can be based on a standard transport cost benefit analysis. The productivity differences are irrelevant. It is only if market failures exist that we need to consider the productivity differences.

This can be seen because, for example, in the case of perfect labour mobility between regions the private value of a job is the same in all places (productivity differences between places being offset by cost of living differences). And (in the absence of market failure) the private value of a job is equal to the social value.

Using the model briefly described earlier Venables (2007) shows the additionality to a transport cost benefit analysis for a situation where agglomeration economies exist and income is taxed. This model forms the basis of the current TAG methodology. This model is extended to the inter-regional context in Venables (2017). Here again if there are no market failures the standard transport cost benefit analysis approach is sufficient. However, if the inter-regional context triggers changes in city size or level of specialisation then agglomeration benefits from both urbanisation and localisation will occur. As mentioned earlier, urbanisation agglomeration economies are the benefits from being located proximate to pure economic mass, whilst localisation agglomeration economies are the benefits from locating similar firms/workers together.

Whilst we are not, in this chapter, specifically concerned with reviewing the detail of the TAG methodology, it is worth identifying that the current method uses an aggregation of changes in government revenues (Income Tax, Corporation Tax and changes in welfare benefits) and applies this to GDP/capita. At this point in time it is worth identifying that this approach moves beyond the model set out in Venables (2007), which is wholly concerned with changes in tax on labour productivity. Chapter 5 presents and reviews the TAG methods.

These wider impacts are additional to user benefits. User benefits therefore need to be correctly estimated in addition to the wider impacts to get a full estimate of the economic value of a transport project. Where M2MLPJ is concerned changes in land use occur. Therefore the user benefits should be based on counterfactuals with variable land uses. This poses some analytical challenges for the estimate of the changes in location attractiveness. The Department at this point in time has

therefore advises for the user benefit calculation to be based on fixed land uses (Department for Transport, 2016).

4.2 M2MLPJ: economic fundamentals

'Moves to more (or less) productive jobs' have two distinct elements; one is the movement of jobs, the other is the movement of workers. These movements may interact with different market failures, in which case they have different economic values and hence treatment in transport appraisal. The two moves are linked, but not in a one-to-one fashion. Suppose that a firm creates 1000 new jobs in region 1, shedding 1000 jobs in region 2. This movement of jobs could be matched by equal movement of workers, who either commute or change place of residence. Alternatively, the additional jobs are filled largely by drawing labour from less productive employment in region 1, and little or no movement of workers occurs, or something in-between.

This section sets out a basic analytical framework to think these points through. There are two parts, valuation and quantity changes. The ***valuation*** question asks, for a given set of moves, are there market failures such that these moves create social value (recalling that in a 'perfect' economy small changes in the pattern of activity are of zero value). We make the case that income tax creates a wedge which means that there may be a social value to moving a worker (through commuting) from a low productivity region to a high productivity one. However, there is no equivalent social value to movement of jobs alone.

We then turn to the more difficult question, ***quantity change***. What moves – of firms and of workers – are likely to be caused by a transport improvement? This is context specific, and the analysis of section 4.2.2 points to the considerations that need to be taken into account in applying these arguments in any transport appraisal. The interaction between moving jobs and moving workers requires quantification of the transmission mechanisms from productivity improvements to wages, from wages to house prices, and ultimately to changes in the housing stock required to accommodate regional population change.

The models below are designed to highlight particular mechanisms, and they abstract from market failures associated with increasing returns to scale and agglomeration. Within the scope of this work they do not cover all the possible combinations household and firm behavioural mechanisms identified in Section 2.3.3. Household mechanisms set out earlier that affect regional labour supply are: commuting, increased/reduced regional labour market participation, and household migration; whilst firm behaviour would include re-location, competing effects between firms in different regions and sectoral shifts between industries (effectively competing demands for labour between firms).

4.2.1 Valuing moves

Spatial equilibrium

There are two regions[11], 1, 2, and a fixed labour force $\bar{L}$ that is divided between regions, so $\bar{L} = L_1 + L_2$. Each region contains firms that produce output using labour with constant returns, so output per worker is a constant $q_i = 1, 2$, where q_i is region specific productivity. The price of output is unity so wages equal value marginal products (also average product under these assumption), $w_i = q_i$.

Households consume goods and housing and have utility function $(1-\theta)w_i - p_i$, where p_i is the price of housing in region *i* and θ is the rate of income taxation.[12] This specification implies that each household has perfectly price inelastic housing demand, consuming one unit of housing. In this sub-section, we assume fixed housing supply in each region, thus fixing the population of each region; movement of workers therefore takes the form of commuting. Each household is able to choose which region to live in, and house prices adjust to equate supply and demand for housing. This implies that house prices, p_1, p_2 adjust such that households are indifferent between regions, this giving the equilibrium condition.

$$(1-\theta)w_1 - p_1 = (1-\theta)w_2 - p_2. \qquad \text{Equation 3}$$

Elements of the model are illustrated diagrammatically below in Figure 4-1. The length of the horizontal axis is the total number of workers, equal to the number of units of housing. The wage curves are drawn net of tax and for productivity levels $q_1 > q_2$. The vertical line captures the housing stock of each region, and hence divides population between regions. The wage in region 1 is greater than that in region 2, and thus consistent with equilibrium as the house price differential adjusts to be the vertical difference $p - p_2$.

Commuting

Residents of region 2 can raise their wage income by commuting to region 1 (the converse obviously not being the case). However, commuting incurs costs which we express (for the marginal commuter) as $C + c(N)$, where *N* is the number of commuters and $c(N)$ is an increasing function. The first term, *C*, is a cost independent of the number of commuters. The second is best thought of as households each having different levels of aversion to commuting, and being ranked by their level

[11] We use the word 'region' throughout, although depending on context the two 'regions' could be a city centre and its suburbs.

[12] Each household supplies one unit of labour, and we assume no differences between amenities in each region; adding such differences does not change the qualitative arguments made here.

of aversion. Thus, if *N* people commute, the marginal commuter has aversion $c(N)$, and intra-marginal commuters are less averse.[13]

Given this structure, the number of commuters is determined by the equation

$$(1-\theta)w_2 - p_2 = (1-\theta)w_1 - p_2 - \big(C + c(N)\big) \qquad \text{Equation 4}$$

The left-hand side is utility from living and working in region 2, and the right hand side is utility from living in 2 and commuting to 1. This simplifies to:

$$(1-\theta)(w_1 - w_2) = C + c(N) \qquad \text{Equation 5}$$

A transport improvement facilitates commuting, and the easiest way to capture this as a change *dC* < 0. The left hand side of equation (5) is constant, so the change in the number of commuters is

$$-dN/dC = 1/c'(N) > 0. \qquad \text{Equation 6}$$

The social value of this reduction in commuting costs is the direct cost reduction *dC* affecting *N* commuters plus, for the *dN* new commuters, the increased value of output minus their commuting costs. Denoting social value *W*, this is:

$$dW = NdC + [(w_1 - w_2) - (C + c(N))]\, dN \qquad \text{Equation 7}$$

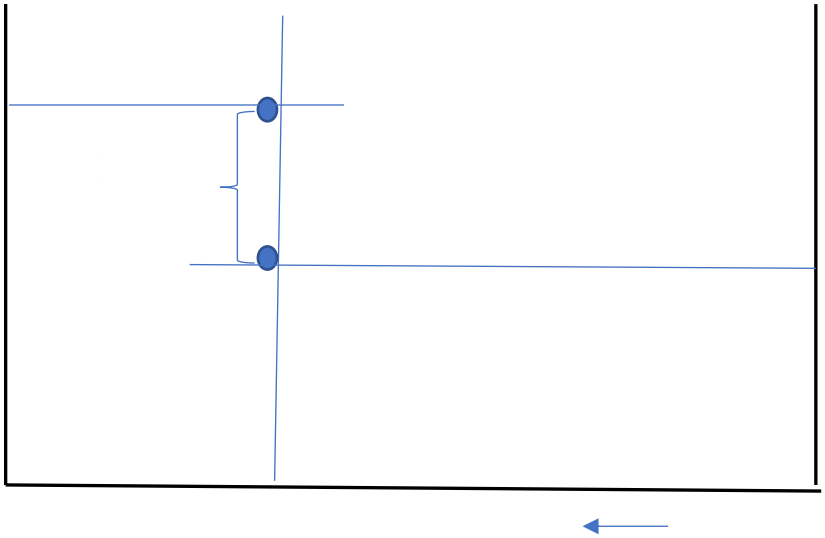
Using the household indifference condition, (3), this is

$$dW = NdC + \theta(w_1 - w_2)\, dN \qquad \text{Equation 8}$$

The first term is the direct effect of the transport improvement ('user benefit'), and the second is the 'wider-benefit'. Household commuting choices are distorted by the fact that commuting costs are not income tax deductible (inevitably, to the extent that they are psychic rather than monetary costs). Increasing commuting therefore brings welfare gain, which turns out to be exactly equal to the tax revenue raised by the increase in commuting. This is the standard argument, developed for Crossrail and underpinning part of TAG. Notice that this argument makes sense for commuting from the low wage region to the high wage, i.e. commuting to more productive jobs. Commuting the opposite direction -- living in an expensive region and commuting to a low wage region – is not worthwhile.

[13] Aversion could be because of distance to be commuted, as in the standard monocentric city model. An alternative interpretation is that commuting becomes congested, creating costs that increase with N.

FIGURE 4-1: EQUILIBRIUM HOUSE PRICE DIFFERENTIAL.



Firm location

We now construct an exactly similar argument, but with quite different conclusions, for firm location. Suppose that a firm operating in region 1 with productivity q_1 can set up activity in region 2, bringing with it its region 1 productivity, q_1.[14] The per worker gain for the firm from investing in region 2 is $q_1 - w_2$, since in region 2 the firm pays local wages, w_2. However, the marginal firm that does this incurs a per worker cost $K + k(M)$, where *M* is the number of firms that make this investment; the cost can be thought of as additional transport and communication costs incurred by operating in the new location. Analogous to commuters, firms are heterogeneous, and are ranked according to the cost they incur in becoming established in region 2. Firms set up in region 1 up to the marginal firm which makes zero profits from so doing, i.e. the equilibrium value of *M* is given by solving

$$\left(1 - \tilde{\theta}\right)[q_1 - w_2 - (K + k(M))] = 0\,. \qquad \text{Equation 9}$$

In this equation $\tilde{\theta}$ is the rate of corporate profits tax which (as written here) is neutral between wage costs and transport and communication costs.

A transport improvement reduces *K*, increasing the number of firms investing in 2 and meaning that $-dM/dK = 1/k'(M) > 0$ workers in region 2 move to higher productivity jobs. The gain to society from the reduction in *K* is the direct cost reduction dK affecting *M* workers, plus, for the *dM*

[14] Or at least, a productivity level higher than q_2. In this section we choose units such that each firm employs one worker (purely in order to save on notation).

additional firms and workers that now move, the increased value of their output minus the cost of having moved, i.e.

$$dW = MdK + [(q_1 - q_2) - (K + k(M))]\, dM \qquad \text{Equation 10}$$

Using the marginal firm's indifference condition, (9), and the fact that $q_2 = w_2$, this is simply

$$dW = MdK \qquad \text{Equation 11}$$

The gain is simply the user benefit (cost reduction *dK* times the *M* firms to which it applies) and there is no wider-benefit (or wider-cost) from the improvement. The difference between this and the commuting case arises because, in the commuting case, a worker changes behaviour to make a gain from the transport improvement, and workers' choices are distorted by the income tax wedge. In the firm location case the firm changes behaviour to gain from the transport improvement, but (if corporate taxation is neutral between the various costs involved) there is no distortion and no wider benefits or costs. Notice that this firm location argument is necessarily from the high- to the low-productivity region, since the firm gains from bringing its higher productivity to a lower wage place.

Remarks

The cases outlined above use similar arguments, but are different in two respects. First, household choices are distorted by the tax system while firm choices are not. Essentially, households are taxed on income and cannot deduct costs associated with alternative locational choices; firms are taxed not on gross revenue, but on profits, i.e. revenue net of these and other costs. Second, commuting will run from a low productivity region (or place) to a higher productivity region. Investment – if firms can move at least some of their productivity advantage while paying local wages – will flow from a high productivity region to a low productivity region.

In this framework then, the wider-benefits argument applies to transport investments that facilitate workers in region 2 accessing higher productivity jobs through commuting out of the region; but does not apply to transport investments that facilitate workers in region 2 accessing higher productivity jobs through movement of firms into the region.

4.2.2 Moving jobs and moving workers

What is the relationship between moving jobs and moving workers? This is context specific, but central to understanding the extent to which the 'move to more productive jobs' distortion is applicable. To explore this a somewhat richer economic framework is needed, with two further elements. First, to better capture job creation/loss we need to describe labour demand, particularly in the region experiencing the transport improvement; we do this by using a standard production function with diminishing returns to labour employed in the region. Second, to capture worker moves we need to describe housing supply, which we do by assuming a supply (marginal cost) curve for housing in the regions.

As before, there are two regions, 1, 2, and a fixed labour force $\bar{L}$ that is now endogenously divided between them, $\bar{L} = L_1 + L_2$. We assume productivity in region 1 is fixed at q_1, while in region 2 there is production function, $q_2F(L_2)$, which may exhibit diminishing returns to labour and hence a downward sloping labour demand. These labour demand curves are indicated – net of income tax – by the lines $(1-\theta)q_1$ and $(1-\theta)q_2F'(L_2)$ on figure 4.2. The elasticity of the region 2 labour demand (marginal product of labour) schedule is denoted η.

The amount of housing in a place depends, in general, on its price. We assume that housing supply in region 1 is infinitely elastic so price is fixed at p_1. (This is a reasonable assumption if region 1 is very large compared to region 2, so the changes we study have negligible effect in region 1). In region 2 the housing supply curve is $H_2 = S(p_2)$, with elasticity ε. The inverse of this relationship is the marginal cost of housing in the region, and we continue to assume each household occupies one unit of housing ($H_2 = L_2$). With no commuting, we can therefore write, $p_2 = mc(L_2)$. Full details of this are given in Annex A.[15]

The initial equilibrium of this model is assumed to be the division of population at point A on figure 4-2. At this point productivity is lower in region 2 than in region 1 and there is a house price differential $p_1 - p_2$. There is no incentive for anyone to move, as utilities are equalised, $(1-\theta)w_1 - p = (1-\theta)w_2 - p_2$, and no incentive for anyone to build more houses, as $p_2 = mc(L_2)$.

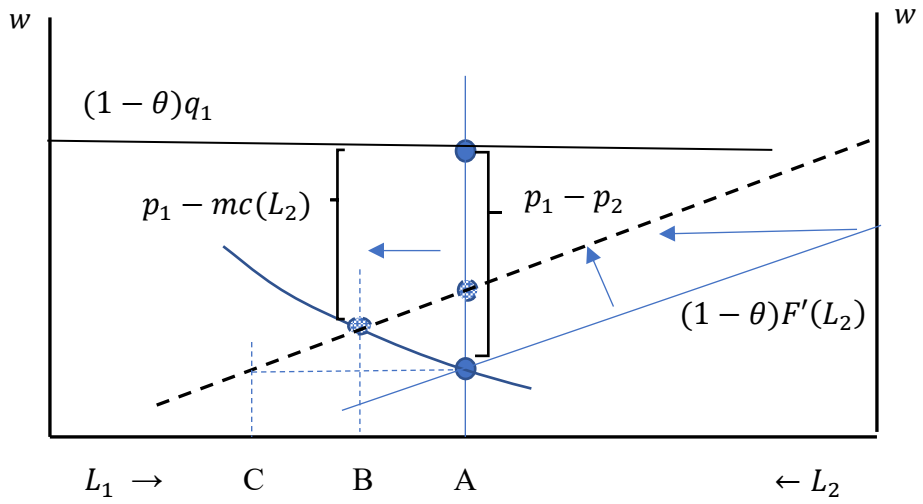
What happens if a transport improvement raises productivity in region 2? We take an extreme case in which productivity q_2 increases for all workers in region 2, so the transport improvement shifts the region 2 wage function upwards to the dashed line. This makes region 2 more attractive for firms and workers, and the quantity response – change in the number of jobs and workers – depends on elasticities of labour demand and housing supply.

If housing supply in region 2 is perfectly elastic then the new equilibrium is with division of the labour force at point C, and wages and house prices in each region unchanged. The position of C obviously depends on the size of the productivity increase (vertical shift in the labour demand curve) and the elasticity of this curve, the number of jobs created being larger the more elastic (flatter) is the labour demand curve. At the other extreme, if housing supply is perfectly inelastic then the division of the labour force is unchanged (there are no quantity changes whatsoever), but wages and house prices in region 2 are bid up. An intermediate case is illustrated at B, in which extra housing is supplied in region 2, but at increasing price and marginal cost. The productivity increase is then split between a wage increase and an increase in the price of housing. The formula for the general case is $\hat{L}_2 = \varepsilon\eta\hat{q}_2/(\varepsilon + \eta s)$, where $\hat{q}_2$ is the proportionate change in productivity (the direct effect or user benefit of the transport improvement), ε and η are elasticities of housing supply and labour demand respectively, and *s* is the share of housing in household expenditure.

[15] This reduces to the model of the previous sub-section if $\eta = \infty$ and $\varepsilon = 0$.

This is a case where the transport improvement raises productivity of all workers in region 2. The same analysis can be given a somewhat different interpretation. Suppose that the improvement causes some firms to 'relocate' to region 2, bringing their region 1 productivity with them, while the productivity of other region 2 firms is unchanged. This is like a horizontal shift in the region 2 labour demand curve, and the number of 'jobs moved to region 2' is the horizontal distance AC. However, the equilibrium ends up at point B, i.e. AC jobs moved, AB workers moved, and BC previously existing jobs in region 2 are destroyed as wages increase and workers moved to incoming jobs. The essential point is that a simple measure of 'movement of jobs' is not the same as the final change in the number of jobs or the 'movement of workers'. The ratio of workers that move to jobs that move is $AB/AC = \varepsilon/(\varepsilon + \eta s)$. This number is less than unity unless housing supply is perfectly elastic.

FIGURE 4-2: JOBS AND WORKERS.



This gives the 'quantity effect' of the change. What is its value? There are two elements. The first is the direct effect of the productivity improvement, $F(L_2)dq_2$, this being, as usual, user benefits plus any productivity effects that might come from other mechanisms (e.g. agglomeration). The second is derived from the tax wedge on household moves, and is $-\theta(w - w_2)dL_2$. This is analogous to that in Equation 8, but whereas commuting into a higher productivity place has positive sign, growing population in a lower productivity place has negative sign. Other changes are occurring – e.g. housebuilding – but as long as these take place at price equal to marginal cost they are of zero net value. However, this additional benefit applies to 'workers that move', i.e. the change in residential population in region 2, dL_2, not to a headline number of 'jobs created'.

Remarks

This section (4.2) draws out the economic fundamentals behind the valuation of moves to more (or less) productive jobs, making two fundamental points.

First, if the market failure arises through (marginal) income taxation, then it applies to ***workers decisions*** of where to work. The intuition is that costs incurred in working in a more productive region (commuting or higher cost accommodation) are not tax deductible. A transport improvement

that increases commuting into a high productivity area creates additional net benefit equal to the increment in income tax revenues. One that causes population to move into a low productivity region has negative effect, equal to the loss of income tax revenue.

Second, changes in the equilibrium location of jobs is unlikely to be the same as claims made about number of jobs created or moved. If new jobs are created in a region this increase in labour demand will generally be met by a combination of worker movement and worker displacement, i.e. workers being bid away from other jobs in the region. The balance between the two depends on elasticities of housing supply and labour demand. These numbers are context specific although one suspects that, for the UK as a whole, housing supply elasticities are generally low although some locations have quite constrained housing supply. In this case net job creation in a region may be a small fraction of the gross number of jobs created or moved, and the 'move to less productive jobs' argument correspondingly less applicable.

Two final points. First, the argument above abstracted from changes in unemployment and participation, further important sources of labour supply. Both are potential sources of wider benefit. Second, in practise, transport improvement affects some firms directly (e.g. those using or producing inter-regionally tradable goods) while other firms (e.g. in non-tradables) receive little or no direct benefit. The final productivity effect will be some weighted average across sectors of the region's economy, depending on elasticities of labour supply and demand in different sectors in the region. Thus, while some sectors in the region will expand, others will contract, releasing labour to those that grow. The net increase in the region's demand for labour and associated wage increase follows from this. To establish the net increase in labour demand it is therefore essential to understand these within region compositional effects.

4.3 Other wider impacts

There is a question as to whether any other market failures, other than agglomeration externalities and income tax, are relevant in the context of a move to more/less productive jobs. To answer this question we draw from a recent review of international economic appraisal practice with respect to wider impacts (Wangsness et al., 2017) and previous work undertaken by James Laird and Peter Mackie for the DfT (Laird et al., 2018). Our view is that other wider impacts could occur at the same time as a M2MLPJ, but these are not specifically productivity related and therefore do not form part of the M2MLPJ methodology. Having said that there is a close relationship between M2MLPJ and dynamic clustering, and consistency is needed in the treatment of M2MLPJ and these wider impacts (labour supply and dynamic clustering).

Table 4-1 presents a summary of market failures and associated wider impacts that can be found in the literature. As can be seen from this table ten market failures have been identified, giving nineteen wider impacts, with seven associated with the labour market. The market failures have been categorised by the factor market they affect, or whether they are directly related to productivity or to commodity markets (for final products). The column on the right hand side identifies those WIs that are included in TAG – as can be seen there are four. Of these, three have

relevance to the movement of jobs between regions – these are shaded green. In TAG the WI associated with Corporation Tax has been incorporated into the M2MPJ method, as the M2MPJ analysis uses GDP/worker and a tax rate that incorporates Corporation Tax. At this point it is worth noting that measurement issues exist for almost all the non-TAG WIs. Furthermore using the CBA+ type approach[16] to calculating wider impacts is likely to give an inaccurate estimate of additionality to a transport costs benefit analysis if multiple market failures exist affecting the same market (e.g. the labour market). In such a situation a modelling tool that brings welfare impacts together in a unique way (e.g. an S-CGE model) is likely to be more suitable.

TABLE 4-1: A FRAMEWORK OF WIDER IMPACTS

Market Failure		Wider Impacts (WIs)		Included in TAG (2018 version)
Productivity effects	Agglomeration externality	Urbanisation		Yes
		Localisation		---
	Knowledge spillovers	Inward investment (e.g. foreign direct investment)		---
		Increased competition arising from increased trade		---
		Innovation impacts in the construction and transport sector		---
Capital Markets	Tax on the return on capital (business profits)	Increased investment in capital		Yes (albeit indirectly)
Labour market	Taxes on the supply of labour	Increased labour supply from a change in commuting costs	Changes in the number of people choosing to work	Yes
			Changes in the number of hours worked	---
		Move to more, or less, productive jobs		Yes
	Spatial mis-match between labour demand and housing, immobility in housing market, sticky wages/over-regulated labour market	Excess labour supply effects	Employment impacts from building transport infrastructure	---
			Employment impacts from operating transport infrastructure	---
			Displacement of labour to region with excess supply of labour	---
			Labour demand impacts from increased output due to international trade	---
	Search costs due to lack of mobility/options	Thin labour market effects		---
Land marke	Over or under regulated land market	Interaction with inefficient land-use regulation		---

[16] In this approach each Wider Impact is calculated independently from the others and added to the transport cost benefit analysis. This approach is embodied by TAG.

	Non-marginal costs and/or imperfect information	Coordination failure	---
Commodity markets	Monopolistic competition arising from e.g. product differentiation, spatial monopolies, etc.	Output change in imperfectly competitive markets	Yes
		Increased competition as a result of better transport (reducing monopolistic competition)	---
	Indirect taxation	Output change in markets distorted by inefficient indirect taxation	---

Sources: Laird et al. (2018).

We can imagine that a move to a more/less productive job could impact on a regional economy in such a way that other market failures than tax and agglomeration effects will be relevant. For example a transport investment in a lagging region with low productivity may:

(i) Expand output
(ii) Encourage inward investment
(iii) Encourage development(e.g. new housing) in areas where planning regulations are inefficient
(iv) Increase labour supply
(v) Reduce unemployment (during construction, as part of its operation or by increasing the size of the regional economy)

Our view is that all these WIs are in principle are worthy of consideration for inclusion in a cost benefit analysis – subject to the caveat above about measurement. However, in the context of the scope of this study the WIs are not directly related to the productivity differences between the regions between which the jobs and households move between.

4.4 The re-balancing agenda

Moving jobs to less productive areas resonates particularly well with the government agenda associated with re-balancing the economy. Reducing productivity disparities among regions is a policy goal of the Government. Therefore there seems to be a degree of perversity in the fact that the M2MLPJ methodology reduces the benefit (because of the tax loss) from shifting jobs from high productivity to low productivity regions.

However, the inclusion of changes in taxation has to be seen as an adjustment to the cost benefit analysis. Such adjustments are necessary to ensure that the welfare value is neither under nor over-estimated. It may seem to work against policy in some situations, and in that sense it is similar to the adjustment for indirect taxation in the standard cost benefit analysis, which appears to penalise public transport modes that abstract demand from road traffic.

If there are additional benefits to locating jobs in low productivity regions then a good economic analysis should examine the market failures present within the recipient region to see, for example,

if any of the market failures listed in points (i) to (v) are relevant. Does the region have high unemployment, is planning permission difficult to obtain, etc?

A further argument associated with re-balancing also exists, which is making better use of the stock of infrastructure we currently have. Supposing infrastructure across several fields (transport, energy, water, health, education) in the south east of England is highly congested and there exists spare capacity in other regions of the country. Then there may be efficiency gains if economic activity and population can be located in places where this spare capacity exists[17]. To date though we are not aware of any analysis that would support this proposition from an economic perspective. The research that would underpin it still needs to be undertaken.

These broader Wider Impact measurement issues mean that re-balancing type arguments regarding shifting employment from high to low productivity regions need to be made in the Strategic Case part of the Transport Business Case, rather than in the Economic Case. We do however consider that Wider Impacts should be enumerated as far as possible, even when they seem to work against policy direction.

[17] If there are efficiency gains to be made the implication is that the price of infrastructure use does not equal social marginal costs, and the P/MSC ratio differs across places for various reasons.

5 TAG GUIDANCE

In this section we provide an overview of M2MLPJ appraisal guidance as contained in TAG and illustrate it with an example. We then benchmark the guidance against the theory presented in Chapters 2 and 4. This leads us to identify a number of critical issues some of which are in scope of this work, and other issues related to M2MLPJ but are not in scope of this work.

In scope:

- *Not all the behavioural mechanisms underpinning the M2MLPJ are encompassed within TAG*
- *TAG uses GDP/worker as an input, whilst the conceptual framework and productivity differentials themselves are cast in the context of labour productivity; and*
- *The productivity differentials in TAG are uniform and do not differentiate by industry, city size, variations within an LAD (e.g. city centre vs suburbs) and over time.*

Out of scope:

- *Tax wedge parameter of 0.3 (not withstanding the issue about GDP/worker differentials vs labour productivity differentials);*
- *User benefits under variable land use; and*
- *Consistency with other related wider impacts particularly labour supply and dynamic clustering.*

5.1 Overview of M2MLPJ in TAG

TAG sets out the method by which the GDP effects and wider impacts of M2MLPJ should be calculated. This is contained in various parts of the guidance, but *Unit A2.3 Employment Effects* is the key one (Department for Transport, 2018b). This unit describes the formulas and parameters in which the value of the relocation of employment should be calculated. The relevant parts of it are reproduced in Annex B. The productivity differentials that form one of the parameter sets in the calculation are contained in the *Wider Impacts Dataset* (Department for Transport, 2019b).

Another relevant part of the Department's guidance is the *Value for Money (VfM) Framework*. This indicates that monetised values for M2MLPJ are treated as an 'indicative monetised impact'. As such they do not form part of the project's NPV or BCR, but are instead used to sensitivity test how robust the final VfM is to different underlying assumptions (Department for Transport, 2017 p22). Other elements of the wider impacts analysis that also fall under this 'indicative' category are dynamic clustering, and induced investment (including dependent development). All of these impacts require land use change. These land use change wider impacts are also known as Level 3

impacts[18] – based on the categorisation of Levels in the overarching wider impacts TAG Unit A2.1 (Department for Transport, 2018a pp13-15). It is in this TAG Unit (p14) that the requirement to base user benefits on fixed land uses, even when undertaking a Level 3 appraisal with changes in land use, is set out.

The M2MLPJ is clearly predicated on land use change. TAG therefore offers guidance on the modelling of land use change with the Supplementary Economic Modelling note (Department for Transport, 2018c). This note identifies different model types and sets out the criteria for a good model.

5.2 Hypothetical example of M2MLPJ guidance

We illustrate the M2MLPJ guidance with a hypothetical example. This example is adapted from the Transport Infrastructure and Economic Performance short course that James Laird and Dan Johnson give to transport professionals. In the example we have three settlements: A, B and C as illustrated in Figure 5-1 and Table 5-1. A road improvement improves connectivity between A and B, and via B onwards to C. This initiates a movement of jobs from A to B and from C to B. There is also a net increase in labour supply. As with a lot of land use modelling, whilst we know the changes in net employment for each settlement, we do not know the underlying mechanism that gives rise to the change. That is we do not know whether the movement in jobs is also followed by household migration (from A to B and C to B) or whether the regional labour markets adjust so that changes in regional labour supply are just accommodated within the region.

[18] A Level 1 analysis is based on 'Established Monetised Impacts' which are: journey time savings, VOCs, accidents, physical activity, journey quality, noise, air quality, greenhouse gases and indirect tax. A Level 2 analysis will include 'Evolving Monetised Impacts' which are: reliability, static clustering, output in imperfectly competitive markets and labour supply.

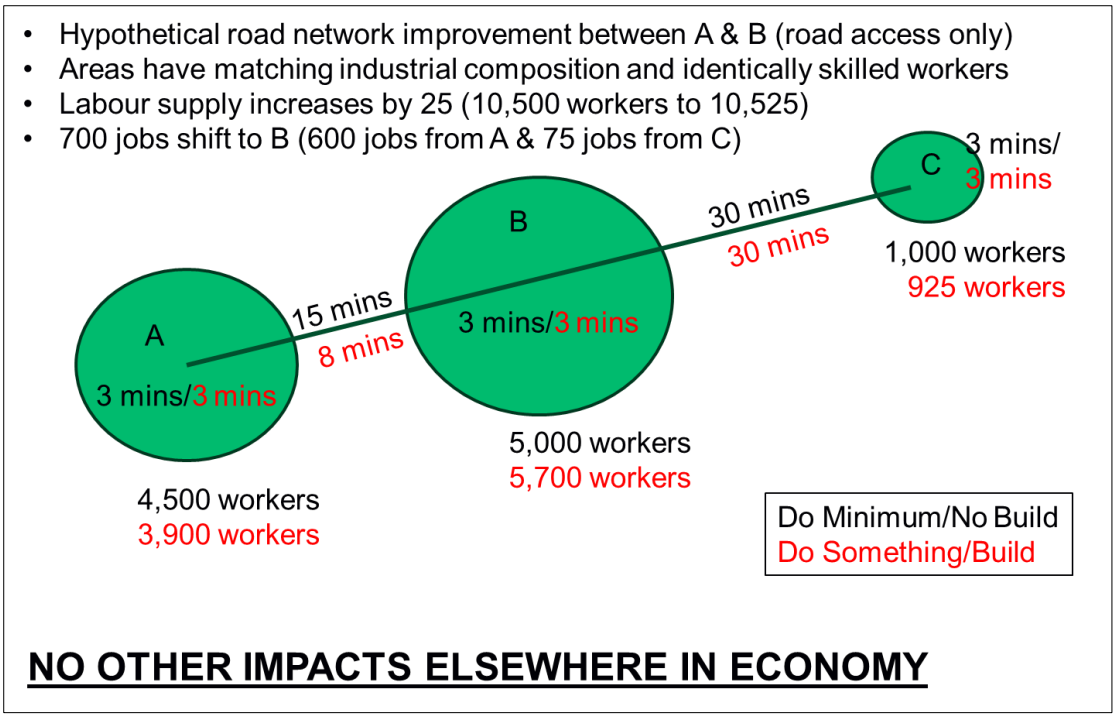


FIGURE 5-1: HYPOTHETICAL EXAMPLE TO ILLUSTRATE M2MLPJ IN TAG

TABLE 5-1: HYPOTHETICAL M2MLPJ EXAMPLE SOURCE DATA

Zone	GDP per worker (2021 in 2010 prices)	Median gross earnings (2021 in 2010 prices)	GDP Differential (against national average)	Average earnings differential (against national average)	Productivity Index	Employment	Before GDP £M
GB	**£58,945**	**£22,500**	**0.0000**	**0.0000**	**0.0000**	**---**	**---**
Zone A	£54,124	17,776	-0.0818	-0.2100	-0.0385	4,500	£243.558
Zone B	£53,632	22,745	-0.0901	0.0109	0.0352	5,000	£268.160
Zone C	£46,179	20,977	-0.2166	-0.0677	0.0180	1,000	£46.179

Note: (1) To ensure an element of realism some of the data is sourced from the DfT's wider impacts databook. These data are GDP/worker in 2021, median gross earnings per worker in 2021 and the productivity index. Zone A is sourced from Kirklees, Zone B from Leeds and Zone C from York. GDP averages per zone calculated using WebTAG employment by sector (excludes primary sector and public sector). GB average earnings calculated using a weighted average on total employment (sourced from the wider impacts databook)

Following TAG (reproduced in Annex B) the first step is to calculate the change in GDP due to the regional productivity differences. This calculation is reproduced in Table 5-2. This gives a net increase in GDP of approximately £2.7M. The second step is to calculate the WI. This is reproduced in Table 5-3. Here we can see that the increase in GDP has been associated with a £0.8M M2MLPJ Wider Impact.

TABLE 5-2: EQUATION 5: GDP IMPACT OF M2MLPJ CALCULATIONS (SINGLE YEAR – 2021 AT 2010 PRICES)

Move to more/less productive jobs	Change in jobs	Productivity Index	Average GDP in GB (2021)	Change in GDP due to productivity differences
Area A	-600	-0.0385	£58,945	£1,360,494
Area B	675	0.0352	£58,945	£1,400,446
Area C	-75	0.0180	£58,945	-£79,660
Total	**0**			**£2,681,280**

Note: (1) This table shows the change in GDP relative to the average GDP/worker in the UK – which is how the M2MLPJ GDP change is calculated. It does not show the change in GDP in Areas A, B or C. In part this is because we can only observe the average GDP/worker, and not the GDP output associated with a job/worker that moves location.
(2) These data have been calculated applying the M2MLPJ TAG formulae detailed in Annex B. However, the productivity index is in fact an elasticity and therefore the TAG formula is an approximation.

TABLE 5-3: EQUATION 6: WIDER IMPACTS – TAX REVENUE

Change in GDP due to productivity differences	£2,681,280
Tax wedge	0.3
Wider Impact due to M2MLPJ	**£804,384**

5.3 Benchmarking TAG M2MLPJ guidance against the theory

Benchmarking against the theoretical discussions in Chapters 2 and 4, there are a number of important features of this calculation which it is worth emphasising. These are set out below.

EMPLOYMENT CHANGES

1. **Regional/LAD changes in employment.** The discussion in Section 2.3.3 identified three mechanisms for firms associated with a M2MLPJ. These are out-competing rivals and capturing market share (this would include new firm start-ups); firms re-locating; and firms in different industries competing for labour. The TAG calculation uses net changes in employment at a regional or Local Authority District (LAD) level, with no regard for industrial sectors. This when taken with the productivity indices discussed later implies that the re-location of jobs is like for like. A financial services job moves from Croydon to the City of London or vice versa – either because the company physically relocates, or because of competition effects between similar businesses located in the different regions. It does not permit a sectoral change from say a rural worker taking a city job, or vice versa.

TAG is therefore incomplete with respect to all the mechanisms that can give rise to M2MLPJ. We consider this further in Chapter 6 of this report.

GDP

2. **Regional/LAD differences in GDP and wages.** The TAG calculation **correctly** does **not** use differences in regional/LAD GDP values or wages, as these reflect compositional and structural differences between regions or LADs. Due to these compositional differences, an index based on GDP/worker differences or on wage differences would exaggerate the real productivity differences between regions. The difference between an index based on GDP/worker or wages and the actual productivity differences can be seen by comparing columns 4 and 5 with column 6 in Table 5-1. It is the productivity index (column 6) that is used in the guidance, and this is correct. In Chapter 7 we will go on to review the robustness of these indices.

3. **GDP or wages.** The economic model set out in Chapter 4 and the associated published literature, for example Venables (2007), is couched in the context of a tax on labour. TAG however applies this method to all forms of taxation and uses GDP as an input to the calculation rather than wages. This issue was raised in the peer review work undertaken by James Laird, Tony Venables and Peter Mackie for the Department when it released the current guidance (see Department for Transport, 2016 p25). It is very relevant to the context of this review and we will consider it in more detail in the subsequent chapter (Chapter 6).

PARAMETERS

4. **Productivity differentials.**
   The discussion in Section 2.1 identified two principal sources of spatial productivity differentials: differences in endowments and differences in agglomeration. The former is a broad category that encompasses environmental factors such as sunshine and soil fertility and institutional factors such as regulatory, governance, financial, etc.

   a. **Labour productivity or TFP.** The productivity indices contained in the TAG wider impacts databook relates to differences in labour productivity (i.e. wages) and not Total Factor Productivity (i.e. GDP). TAG applies them to GDP and therefore treats the labour productivity differentials as a TFP differential.

   b. **Uniform productivity differentials across industries.** The productivity differentials in TAG are common across all industries. However, there exists different returns to agglomeration by industry. We can see this for example in the agglomeration elasticities in TAG, which are disaggregated by industry groupings. With agglomeration being one of our sources of productivity differentials, we would expect productivity differentials to vary by industry.

c. **Uniform productivity differentials across city size** Furthermore, given the existence of variable returns to agglomeration we might also expect the productivity differentials to vary with the size of the cities at the origin and destination end of the move – as these will affect the relative productivity differentials between locations. This will vary by industry as different industries have differing variable returns to agglomeration.

d. **Productivity differentials by LAD.** Another agglomeration related point is that productivity differences vary substantially within LADs, with high workplace productivity found in city centres and much lower productivity found in the suburbs. The use of an average productivity differential for all firms in a LAD, as TAG recommends, would then overstate the productivity loss of a shift of a firm from a suburb in a high productivity LAD, to a lower productivity region. A more nuanced spatial disaggregation of the productivity differential may therefore be necessary, to capture the true effects on productivity of an M2MLPJ.

e. **Productivity differentials over time.** The productivity differentials in TAG are fixed over the appraisal period. However, there is an expectation of significant background land use change that will occur over the same period. This will change the relative size of different agglomerations and therefore the productivity differentials.

The productivity differentials are central to the calculation of the M2MLPJ and we consider their estimation and desired level of disaggregation further in Chapter 7 of this report.

5. **Tax wedge.** The model presented in **Error! Reference source not found.** identifies the value o f a job move between locations is related to the income tax rate ϑ. The TAG M2MLPJ tax parameter is 0.3 and dates to the original DfT 2005 discussion paper (Department for Transport, 2005). The derivation of this parameter relates to the total tax take from a change in GDP – and is not specifically related to the change in taxes on labour. A review of this parameter and the labour supply tax parameter was identified as an area for further research when the DfT published its review of the wider impacts guidance in 2017 (Department for Transport, 2016 p27). This review has not yet been undertaken and, beyond noting its need in the context of valuing the M2MLPJ and referring to it in Chapter 8 in the discussion on future work, is not considered further in the context of this review. However, in Chapter 6 we consider the conceptual issue as to whether the M2MLPJ tax parameter should also include non-labour taxes such as corporation tax, excise duties and VAT.

USER BENEFITS

6. **User benefits with variable land use.** The full value of the M2MLPJ requires the accurate measurement of user benefits with variable land use. This is because when land uses change, zonal attractiveness also changes. If this change in attractiveness is not captured

within the user benefit calculation then the total economic benefit of the relocation of economic activity will not be correctly estimated. In the 2016 review of the new wider impacts guidance concern was expressed about the use of fixed land uses for the calculation of user benefits and this was identified as an area of further research (Department for Transport, 2016 p28). This research remains outstanding, but a further commitment by the Department to examining this issue has been committed to in the recent Appraisal and Modelling Strategy (Department for Transport, 2019a p27). Beyond noting its need in relation to the accurate measurement of M2MLPJ, and referring to it in Chapter 8 in the discussion on future work we will not consider it further in this review.

OTHER RELATED WIDER IMPACTS

7. **Dynamic clustering.** The changes in employment that give rise to M2MLPJ will also give rise to dynamic clustering benefits. Clearly the two are inter-related. An analyst should not be calculating one wider impact (e.g. M2MLPJ) without doing the other one (i.e. dynamic clustering) – a relatively minor point, but TAG should possibly emphasise this.

8. **Regional/LAD labour market changes.** The calculation in TAG is based around employment differences at a regional/LAD level. Whether households migrate between LADs, commute between LADs or whether workers drop out of the labour market in some LADs and enter the labour market in others is immaterial to the calculation. There is no additional net welfare gain of these changes on top of user benefits and the wider impact calculated. If, however, there exist labour market imperfections beyond an income tax on earnings (e.g. giving rise to high levels of unemployment), then how households respond becomes material to the calculation of the total economic impact. We would see such calculations, whilst related to M2MLPJ wider impact, as being associated with other wider impacts (see Table 4-1 and associated discussion in Chapter 4).

9. **Changes in regional/LAD labour supply.** Related to the above point about regional labour market changes. If households do not migrate (or commute) between regions/LADs then regional/LAD labour supply needs to adjust – as residents drop in or out of the labour market. Contraction and expansion of regional/LAD labour supply is one of the mechanisms that facilitates the M2MLPJ. This then raises an issue about the consistent treatment of workers between the wider impacts of M2MLPJ and increases in labour supply. The TAG guidance on changes in labour supply assumes 'new' workers are less productive than existing workers, and also applies a higher tax wedge to them (see also the previous comments on the tax wedge below).

   Whilst noting the interactions between the M2MLPJ guidance and other aspects of the Wider Impacts guidance in TAG, we will focus the remainder of our discussion in this review on the M2MLPJ guidance. In recommending future research on M2MLPJ in Chapter 8 we do draw attention to these interactions.

6 M2MLPJ: GDP OR WAGES

In this section we consider whether GDP or wages should be used in the M2MLPJ guidance. Specifically we:

- *Consider the impacts on GDP of a M2LPJ, and find that GDP may stay the same, or go up or down. It is context dependent. Currently guidance would imply it would always go down.*
- *Consider whether it is appropriate to 'bundle' wider impacts associated with income tax, corporation tax (affects capital investment) and indirect taxation together. We consider that they should not.*
- *This leads us to recommend that the TAG M2MLPJ guidance should be adjusted to be based solely on wage differentials between regions, and the tax wedge parameter to be based solely on the marginal rate of income tax. GDP predictions should be based on explicit modelling of GDP using the supplementary economic models described in TAG.*

6.1 GDP impacts of a M2MLPJ

6.1.1 GDP changes in a simple two region model

To illustrate the impact on GDP of an intra-regional transport investment we take a highly simplified, but illustrative two region model – see Figure 6-1. Each region produces one good, which is the same in both regions. Inter-regional transport and trade costs are zero, and therefore the equilibrium price of the good is P in both regions. Region B is more productive than Region A, and therefore produces more of the good than Region A. For ease of illustration we also assume that the total quantity of the good produced in each region (Q_0^A and Q_0^B) is consumed in that region.

In this example we focus on the mechanism of regional competition between firms set out in Section 2.3.3 – that is firms in Region A (the lower productivity region) begin to outcompete firms in Region B, capturing market share from them and exporting more of their product. We also focus on the household behaviour mechanism of workers dropping in and out of the labour market – rather than either commuting between regions or migrating between regions (also see Section 2.3.3). This simplifies the analysis considerably. Thus in Table 6-1 we are focusing on the cell from the second row and the second column (coloured amber).

TABLE 6-1: FIRM AND HOUSEHOLD M2MLPJ MECHANISMS

ΔRegional labour supply is:	Employment change occurs between firms		
	In the same industry		In different industries
	Re-location from one region to the other	Competition effects between firms in different regions	Move to industry with lower/higher value added
Serviced by inter-regional commuting			
Drawn/released to regional labour market			
Serviced by household migration			

Note: cell colouring is to aid interpretation of the discussion contained in this chapter.

A transport investment in Region A raises productivity via the mechanisms discussed in Chapter 2. This is represented by a downward shift in the supply curve (from S_0^A to S_1^A). In the short run, with fixed factors of production, more output is produced and the price of the good lowers. Region A will start exporting to Region B. Production in Region A expands, whilst there is a contraction of production in Region B. In the long run output will expand further through induced investment and an increase in the regional labour supply. This ultimately leads to a new equilibrium where exports and imports balance. In this equilibrium the price of the good is P_1, $Q_1^{A\prime\prime}$ is produced in Region A, but only $Q_1^{A\prime}$ is consumed there. The remainder is exported. In Region B, $Q_1^{B\prime}$ of the good is produced whilst $Q^{B\prime\prime}$ is consumed. The difference is imported.

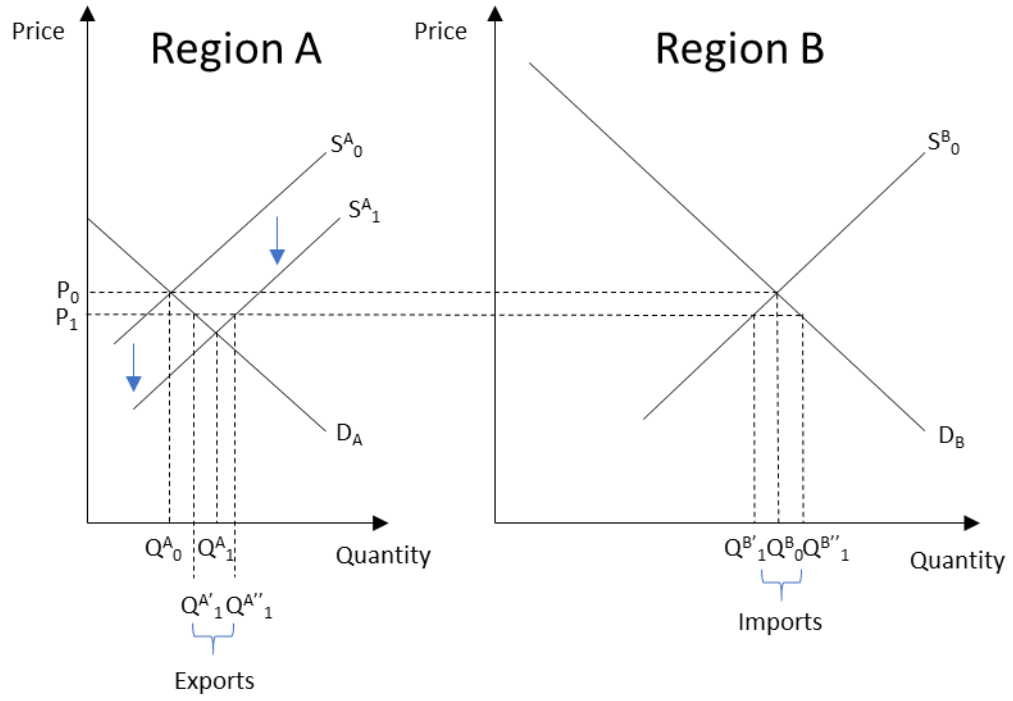


FIGURE 6-1: REGIONAL TRADE FOLLOWING A TRANSPORT INDUCED INTRA-REGIONAL PRODUCTIVITY SHOCK.

The transport investment has increased output and therefore GDP. The Laspeyres measure of GDP (at pre-investment prices) gives the increase in GDP as:

$$GDP_{total} = P_0\left[\left(Q_1^{A\prime\prime} - Q_0^A\right) - \left(Q_0^B - Q_1^{B\prime}\right)\right] \quad \text{Equation 12}$$

At the post transport investment equilibrium position, there has been a contraction in output in Region B, and an expansion in output in Region A. That is output has been displaced from Region B to Region A, and employment will also have been displaced. This is the M2MLPJ.

If, however, trade between the regions was not possible, there would be no displacement of jobs from Region B to Region A. This is because in this counterfactual there would only be impacts in Region A. In this situation output in Region A would be Q_1^A, whilst there would be no change in output in Region B. That is Region A's output is lower than when M2MLPJ between the regions occurs. Whilst Region A's production is lower in this 'isolated' situation, its consumption is higher – as all the output produced in the region is now consumed in the region. In this 'isolated' scenario the change in GDP is given in Equation 13.

$$\Delta GDP_{Isolated} = P_0\left(Q_1^A - Q_0^A\right) \quad \text{Equation 13}$$

Comparing Equation 12 and Equation 13 the additional increase in GDP due to the displacement of economic activity from Region B to region A and the exporting of some of the output from Region A to Region B (GDP_{M2MLPJ}) is:

$$GDP_{M2MLPJ} = GDP_{total} - GDP_{isolated}$$

$$GDP_{M2MLPJ} = P_0[(Q_1^{A\prime\prime} - Q_1^A) - (Q_0^B - Q_1^{B\prime})] \quad \text{Equation 14}$$

Whilst the total GDP of Regions A and B will always expand from a productivity shock in Region A, the outcome on total GDP against a counterfactual where the impact is wholly contained in Region A (i.e. GDP_{M2MLPJ}) is dependent on whether the increase in production in Region A (against this counterfactual) offsets the reduction in production in Region B. That is whether the difference between Q_1^A and $Q_1^{A\prime\prime}$is greater than the difference between Q_0^B and $Q_1^{B\prime}$). This is dependent on how elastic the demand and supply curves are. It is therefore context dependent, and in certain situations GDP may stay the same, increase and in other situations it may contract. Some intuition from the model in Figure 6-1 gives a sense as to when these different outcomes will occur .

(i) If the regional demand and regional supply schedules in the different regions have the same slope then $Q_1^{A\prime\prime} - Q_1^A$ is the same as $Q_0^B - Q_1^{B\prime}$, and GDP is zero – that is GDP does not change. This is as depicted in Figure 6-1. This could be associated with an industry where the production technology is transferable and demand preferences are relatively homogenous across regions;

(ii) If the supply curve in Region A has a lower slope than in Region B then GDP_{M2MLPJ} will be positive and GDP will therefore expand. It will be negative (and GDP will contract) if Region A's supply curve is steeper; and
(iii) If the demand curve in Region A is steeper than in Region B then GDP_{M2MLPJ} will be positive and GDP will therefore expand. It will contract if it is flatter.

This context dependency on the change in GDP from M2MLPJ is in contrast to the expected change in welfare. This is because welfare will always increase from the M2MLPJ, as the increase in producer surplus more than offsets the reduction in consumer surplus in Region A, and vice versa in Region B.[19]

A criticism of this simple model is that it does not take account of changes in income from a shift in economic activity from the high wage (productivity) region to the low wage (productivity) region. This will have the effect of shifting the demand schedules of Region A and Region B, as households in Region B have less income and households in Region A will have more income.[20] This net reduction in income needs to be layered on top of the three potential contexts on the shape of the demand and supply curves identified above. Where gross of tax wages are given as w, and the labour displaced from Region B to Region A is given as N workers, this would imply an adjustment to equation 16 as follows:

$$GDP_{M2MLPJ} = P_0[(Q_1^{A\prime\prime} - Q_1^A) - (Q_0^B - Q_1^{B\prime})] - N(w_0^B - w_1^A) \quad \text{Equation 15}$$

In the simplifying case of scenario (i) where the demand and supply curve slopes are equivalent in Regions A and B then a move to less productive jobs would reduce GDP by $N(w_0^B - w^A)$, However, the sign of the change in GDP cannot be determined a priori in scenario (ii) and (iii) as they depend on the relative slopes of the supply and demand curves in the different regions.

This simple example for one cell in Table 6-1 illustrates the difficulty in predicting a priori the impact of a move to a less productive job on GDP. Within the scope of this work we have not undertaken this exercise for every cell in Table 6-1, but our view is that changes in GDP from a M2MLPJ is context dependent, and therefore ideally we would want a model of the economy model to give us those predictions.

[19] In the M2MLPJ situation the impact on welfare and national income (GDP) diverge. Mohring (1976 Chapter 9) sets out the conditions required for consumer surplus and national income (GDP) to be equivalent: post intervention there should be no change in the use of primary resources, and the same pricing rules for consumer surplus and national income need to be used. These are highly restrictive, and in practice mean that there will invariably be difference in the changes in GDP and the changes welfare brought about by a transport investment. He also notes that differences occur between GDP and consumer surplus measures if the "supply of primary factors are positively (or negatively) related to the real earnings rates of these factors" – e.g. an upward sloping labour supply curve.

[20] In this model we are assuming there is no taxation, and re-distributive welfare payments to households.

6.1.2 Changes in GDP with M2MLPJ

We are now in a position to answer the third objective of this study. That is what the rationale is in TAG for output per worker being valued lower in areas with low productivity even though the market price of the good is common across all areas, and to review whether TAG's treatment of changes in GDP is correct.

In the first instance the analysis in the previous section identifies that a move to a less productive job can lower GDP – even when selling at a world price. The simplifying scenario of equivalent demand and supply conditions in both regions indicates that the reduction in GDP is driven by the differences in wages between the two regions. In this case households are exchanging a welfare benefit from moving regions with a reduction in income. This effect reduces GDP – even though welfare is increasing. However, the size and sign of the GDP change is context dependent.

Current TAG guidance suggests that with a M2MLPJ GDP will change in line with productivity differentials. Possibly it will but this is likely to be coincidental, and is not guaranteed to occur in all scenarios. In the simplifying scenario referred to above, GDP would fall/rise by the difference gross wages between the regions (not the differences in GDP/worker).

In terms of TAG it is hard to give firm guidance on how to predict changes in GDP due to the M2MLPJ, given its context dependency. Our view therefore is that changes in GDP arising from M2MLPJ should be estimated in a model of the economy.

6.2 Government taxation - a source of wider impacts

6.2.1 Government taxation

Government taxation can be highly distortionary. As such if the use of taxed factors/commodities alters as a consequence of the transport investment, the presence of the government tax can be a source for wider impacts in the cost benefit analysis. Table 4-1 in Chapter 4 identifies three specific types of government taxation as sources of wider impacts:

- Taxes on the supply of labour (an income tax). This affects the labour market through labour supply.
- Taxes on the return on capital (business profits). This affects rates of investment and ultimately the productivity of the economy.
- Consumption taxes on goods and services. These include VAT and excise duties (where they differ from a Pigouvian tax). These taxes mean the demand for goods and services differs from the efficient level.

A wider impact would therefore occur if a transport investment brings about changes in the supply of labour, leads to a change in the level of investment or the rate of return on investment or changes the level of output in the economy subject to indirect taxation.

Arguably a M2MLPJ brings about changes in all these aspects of the economy. It is explicitly associated with changes in the labour market and the model presented in Chapter 4, a simplification of Venables (2007), shows that when labour is displaced between regions with differing levels of labour productivity an additional social surplus to the transport user benefits is created. This social surplus is felt by the government as a change in tax revenue from labour.

A transport investment also affects the productivity of and amount of capital in an economy. The economic models presented in Chapter 2, show that improvements in transport services can affect the efficiency of a region, leading to a higher steady state – with more capital and more output – for regions with more transport services. Taxing business profits, and thereby the return on capital, affects investment levels suppressing them below efficient levels. A wider impact would therefore be expected from a transport investment, as this would stimulate additional investment. What that wider impact is in social surplus terms is complex due to the interaction with economic growth. Several recent studies in the OECD for example find that corporation tax is the tax that inhibits economic growth the most (e.g. Arnold et al., 2011, Macek, 2014). We are, however, not aware of any theoretical or empirical study that identifies the additional social surplus to transport user benefits from an increase in capital investment brought about by a transport investment, based on higher returns to capital and increased capital investment. However, given the interaction with economic growth it seems unlikely that it will be equivalent to corporation tax revenues – which is one interpretation of TAG.

Two further challenges exist regarding understanding the full social value of changes in the return on capital and increases in capital investment. They both relate to the modelling of capital investment. The first is there is a need to model how transport investment changes the rate of return on existing capital, and the second there is a need to model the extent to which the transport investment would stimulate additional capital investment. These are likely not to be trivial issues, and will need further research. In fact the treatment of corporation tax was identified as a future research area by the Department when it published its wider impacts guidance (Department for Transport, 2016 p25).

Turning to the third government tax considered here – consumption taxes on goods and services. These taxes distort the market for goods and services, and any expansion or contraction in output would create additional social value to user benefits. Like labour taxes this social surplus is felt by the government as a change in tax revenue. To be able to incorporate this wider impact into appraisal guidance there is a need to predict changes in output. In the context of M2MLPJ this would require estimates of changes in GDP, which as discussed in the previous section is not as straightforward as it may seem. The DfT also identified examining the implications of consumption taxes as part of its future research, when it consulted on the updated wider impacts guidance in 2016 (Department for Transport, 2016 p26).

6.2.2 Implications for M2MLPJ guidance

The above discussion highlights the potential distortionary aspect of different elements of government taxation. However, this is a general discussion and the particular interest of this study is in distortions relevant to M2MLPJ. Here the economic theory presented in Chapter 4 helps us. The

key conclusions coming out of that is that household choices are distorted by the tax system – by the tax on the supply of labour – whilst firm choices are not.

Wider impacts from M2MLPJ occur only through changes in commuting patterns or net changes in the distribution of population between regions. Analysis must therefore explain and quantify the impact of a transport improvement on:

- Demand for labour in the region:
    - Reasons for the change in labour demand
    - Sectors and the proportion of economic activity affected.
- The extent to which the increase in labour demand is met by:
    - Release of labour from other sectors in the region
    - A change in the participation rate
    - Inwards migration;
    - or a reduction in net outwards commuting.

Where unemployment is high labour demand may also be met through a reduction in unemployment.

In terms of the mechanics of the calculation the wider benefits (and costs) of M2MLPJ should only be calculated on changes in earnings, and should use a tax rate consistent with the marginal rate of taxation on earnings. Given the current TAG guidance is based on GDP/capita and uses marginal tax rates that include all forms of government taxation, our recommendation is that this aspect of TAG is altered to be consistent with the theory.

7 PRODUCTIVITY DIFFERENTIALS

In this section we consider the empirical basis of the current productivity differentials in TAG. We consider that:

- *The current differentials, whilst consistent with the methods employed at the time, would no longer be viewed as robust – given how methods and understanding of the biases has improved since 2008.*
- *The original study is comparable to other studies e.g. Gibbons et al. (2014)*
- *The ideal level of disaggregation in the productivity differentials for M2MLPJ is very demanding, and in our view will be difficult to achieve with existing datasets;*
- *An alternative to empirically estimating the M2MLPJ productivity differentials would be to focus on the aspect of the differential arising due to agglomeration (rather than endowment) differences, and use an agglomeration model to estimate these differences.*

7.1 The state of the art

7.1.1 Estimation of place based productivity

Returning to the Cobb-Douglas specification for the production function presented in Chapter 2 but amending to be pertinent to region *i*:

$$Q_i = A_i {L_i}^{\alpha} {K_i}^{1-\alpha} \quad (16)$$

Noting that labour comprises of different skill sets, s_i, and that skills will vary between regions, we can amend this equation to:

$$Q_i = A_i (s_i L_i)^{\alpha} {K_i}^{1-\alpha} \quad (17)$$

The efficiency term, A_i, represents local total factor productivity (TFP) in region *i*. It is the place based productivity variable that is of interest to us. We see this local TFP factor as deriving from endowments, such as sunshine, soil fertility, etc.[21] and agglomeration related sources. For mobile industries (manufacturing and services) the agglomeration related sources are likely to dominate.[22]

[21] Endowments can also cover regulatory, institutional and financial differences. In an inter-regional context within the UK differences in such endowments will be small.

[22] Combes et al. (2008) for France find that the role of endowments on productivity differences is small in the context of France.

For these industries, therefore, the literature on the estimation of agglomeration economies is highly relevant to the robust estimation of the place based productivity effect A_i.

The empirics of estimating agglomeration economies is a field that has seen fairly continual development over the last thirty years. It is still an evolving field. We now briefly introduce some of the key issues that arise when estimating agglomeration economies and briefly outline some estimation methods. This summary is then used to benchmark the robustness of the existing productivity differentials. For thorough discussion on the current position this subject matter the reader is referred to Combes and Gobillon (2015), whilst Graham and Gibbons (2018) provide a shorter discussion with a particular focus of estimating agglomeration economies for use in transport appraisal. The latter was commissioned by the Department.

In terms of the issues that are faced when estimating agglomeration economies, these can be summarised as:

- **Separate identification of skills and local effects.** The variation in labour skills is systematically related to agglomeration economies – that is high skilled labour sorts itself to places with high economic density. If A_i has not been purged of the effects of $s_i L_i$, the derived agglomeration elasticity is sometimes referred to as a people based productivity effect or a composition effect (D'Costa and Overman, 2014). This terminology is also used in TAG.
- **Agglomeration economies and dispersion forces.** Often the empirical literature estimates agglomeration economies net of centrifugal forces. With reference to Table 2-1 such forces would include high land rents and congestion (a diseconomy of scale). It is the combination of centripetal and centrifugal forces that give rise to the variable rates of return to agglomeration.
- **Static and dynamic agglomeration.** Static agglomeration productivity gains are those that occur very quickly (e.g. from matching sources), whilst dynamic effects refer to productivity gains that can take time to build up. Dynamic effects typically stem from the learning sources. The terms static and dynamic in the agglomeration literature are used differently relative to their use in TAG – where they relate to land use change and differing levels of appraisal. The separation of the static and dynamic elements of productivity remains an emerging area with only a handful of published studies. There is a substantial range in the estimation of the dynamic component from small (D'Costa and Overman, 2014) to 60% (De la Roca and Puga, 2017). Empirically the role of sorting, treatment of educational attainment appear important in the empirical approach, with this aspect of the literature evolving quite rapidly.
- **Endogeneity.** There are multiple sources of endogeneity in any econometric specification that attempts to estimate agglomeration economies. That is the causality between productivity and economic mass can run from productivity to economic mass as well as from economic mass to productivity. The main sources of endogeneity stem from the fact that workers will migrate to the more productive locations, that educational attainment (and therefore labour quality) is higher in larger cities, and in larger cities shocks (e.g. wage offers) are more frequent (Combes et al., 2011). Furthermore more productive locations may attract more private (and even public investment) leading to larger economic mass.

> That is higher productivity may lead to higher economic mass due to the non-random nature of where transport projects are located. A further element of endogeneity may arise as markets may be less competitive (i.e. more imperfect) with higher prices and on average less productive firms relative to areas where economic mass is higher and competition is therefore more intense. Here with revenue based output firms that exist in local markets with higher prices will have seemingly higher productivity than those in areas with more competition(Graham and Gibbons, 2018 p30).

Turning to estimation methods. As before the reader is referred to texts such as Combes and Gobillon (2015) for an in depth discussion, or Graham and Gibbons (2018) for a shorter discussion on estimation methods. In essence one of the key difficulties in separately identifying skills and local effects is that worker skills are invariably not fully observed. A fixed effects estimation using a panel dataset focusing on workers or firms that move locations is one approach for addressing this missing variable problem. Unless the firm or worker moves location there is unlikely to be sufficient variation in the data to be able to recover empirically significant parameters on the fixed effects. Instrumental variable approaches in both panel and dynamic panel specifications have also been used successfully to control for the endogeneity problems in the data. However, identifying a suitable instrument is challenging, with successful estimations being based on historical or geological variables as explanatory variables of agglomeration which are exogenous to current levels of productivity. An alternative approach described by Graham and Gibbons (2018) is that of panel control functions or structural estimation approaches. Adapting the specification to incorporate aspects such as static and dynamic agglomeration effects, location choices and heterogenous prices impose further demands on the econometric specifications.

In terms of the data that is used to form the basis of the estimation, the current consensus is that micro-level panel data is best. That is data that is at the firm or worker level is preferable over area wide averages. The general view is that micro panel data captures more variation and allows the use of more sophisticated methods for addressing sources of endogeneity, allows for the incorporation of dynamics and is consistent with micro economic foundations should a control function approach be used.

7.1.2 Disaggregation

Movement to between LADs, but within an industry

Following the discussion in Chapter 5 ideally we would wish to have place based productivity differentials for like for like workers (i.e. otherwise identical workers that work in the same industry but in different places) that vary:

- By local authority (LAD), and
- By industry , and
- By location within LAD reflecting city size and/or central city or suburban locations.

Additionally the factors should vary with the forecast year to reflect changes in background demographics.

Movement between LADs, and also between industries

Where there is a move between regions and between industrial sectors there is a further requirement to have:

- Inter-industry productivity differentials. These differentials would capture the shift in productivity of workers that shift between industries (and locations) as opposed the industry differentials that refer to a shift in economic activity between regions but not industries.

These inter-industry productivity differentials would need to be applied to the intra-industry differentials above.

7.2 Benchmarking the TAG productivity differentials

7.2.1 Estimation

The TAG productivity differentials are based on a research study commissioned by DfT and undertaken by the University of Leeds (Dargay et al., 2008). Their work presented the results of a study of regional productivity differentials for 404 LADs of England, Scotland and Wales based on individual micro-data. The data sets used were three waves of the Annual Survey of Hours and Earnings (ASHE) for 2004, 2005 and 2006. This gave a sample of 503,314 observations, which was limited to 362,200 observations based on a set of exclusions based on age, wage, main job and absences. Hourly wage was further adjusted to regional CPI as a control on regional price variations.

A wage equation was specified:

$$LogW_i = X_i\beta^X + Z_i\beta^Z + L_i\alpha^L + I_i \times L_i\alpha^{IL} + \mu_i \quad (18)$$

The log of hourly earnings for individual *i*, $LogW_i$, was regressed on a set of variables controlling for individual X , employer Z_i, firm and industry effects L_i. The explanatory factors included in the model are age, tenure, occupation, whether full- or part-time employed, gender, firm size, industry and region. A number of different models were estimated using different regional, industrial and occupational classifications. The final model included 81 occupations, 5 industry groups and 405 Local Authority Districts. Industry-region interaction terms, $I_i \times L_{i,}$ were included to control for regional differences in industry composition, which may affect productivity. The estimation method used was ordinary least squares (OLS) and standard errors were adjusted for heteroskedasticity.

The coefficients of interest are in the vector α^L. This vector of coefficients is interpreted as giving a place based productivity coefficient for each of the LADs. It is relative to a nominal regional dummy. They are therefore converted to be relative to a national average job by calculating a weighted average productivity differential and subtracting this from each of the estimated regional productivity differentials. Their econometric estimates of productivity differentials were lower than raw wages by about 40%, so clearly there has been some controlling for individual level factors. The highest differentials are for City of London (39%) and the lowest for West Devon (-26%). It is also useful to note that only 153 of the reported 403 differentials were actually significantly different

from the national average at the 95% level. The authors considered that the resultant productivity differentials were consistent with those found elsewhere, but just presented at finer level of disaggregation. With only just over a third of the LAD productivity differentials estimated statistically significant the author's felt there was sufficient uncertainty in the results to warrant presenting the productivity differentials as confidence intervals, rather than as the mean estimate.

The contribution that Dargay et al. (2008) made was in the empirical estimation of a set of productivity differentials for each and every LAD in Great Britain. They used methods that were considered acceptable for the time (2007)[23], but that we would now consider to be naïve. Nonetheless they used what controls they had available to narrow in on the place based productivity effect. Where the Dargay et al. (2008) research would differ from a modern study using methods described in Combes and Gobillon (2015) and Graham and Gibbons (2018) are in the following areas:

i. **Controlling for individual skills.** Not all of an individual's skills can be observed. In the case of the ASHE data individuals' qualifications are not available – so these are unobserved. Innate ability is also unobserved and is likely unobserved in all datasets. Dargay et al. (2008) used controls by occupation to proxy for the missing skill information. The area-industry ($I_i \times L_{i,}$) interaction term will also pick up differences in worker skill composition between areas, if worker composition is varying systematically by area (within an industry). More recent studies control for unobserved skills in individuals using panel data individual fixed effects. Using individual fixed effects means that identification of area place based effects comes from individuals who move between areas. To recover significant area place based productivity coefficients there therefore needs to be sufficient movers between areas in the sample – which may prove problematic for high levels of spatial disaggregation.
ii. **Regional price variation controls.** Dargay et al. (2008) adjusted the wage to reflect regional price variations.[24] This adjustment resulted in the dependent variable being <u>real</u> wages, rather than <u>nominal</u> wages. However, nominal wages are the metric which should be used to analyse labour productivity differences as these represent how much more firms are willing to pay in larger agglomerations to comparable workers in other agglomerations (Combes and Gobillon, 2015 pp254-255, De la Roca and Puga, 2017 p107). An analysis of spatial variations in <u>real</u> wages would identify spatial differences in standards of living and economic welfare (see for example Gibbons et al. (2011), and not productivity. This is because prices on immobile factors adjust to reflect the productivity differences. Thus low productivity places have low nominal wages, but also a low cost of living – as house prices adjust until returns to mobile factors (real income of households) are equalised across places. It should also be noted that as wages and land prices are simultaneously determined in equilibrium, controlling for land or housing prices can lead to serious endogeneity biases

[23] For example Graham (2007a) uses OLS as an estimation method, and in 2007 the importance of properly controlling for sorting effects had not yet been fully recognised (e.g. as in Combes et al. (2008) and in the UK context the 2010 work by SERC for Northern Way later published in D'Costa et al. (2013)).

[24] This adjustment was undertaken at the specification of the Department.

(Combes and Gobillon, 2015 pp254). Arguably the original DfT study should not have specified the output as real productivity differentials, given that it is nominal wages that reflect the differential that is required for the M2MLPJ calculation.

iii. **Pooling three years of ASHE data** and treating as a cross-sectional dataset. The ASHE data was pooled presumably to increase sample size. However, as it is a panel dataset this results in individuals appearing in the dataset up to three times. These repeated observations (even with changes in nominal wages and potentially some other attributes over the period) bias the standard errors. This is a known issue in stated preference (SP) analysis and the treatment of it has been standard in SP work over the last decade, but was relatively novel at the time this study was undertaken. The standard errors reported by Dargay et al. (2008) are therefore likely to be too small.

iv. **Endogeneity.** Nowadays high quality studies would be expected to make some controls for endogeneity. This could be through some form of IV regression. The evidence on the importance of endogeneity does however vary. If sufficient controls are used for the highly endogenous aspects (e.g. workers' skills) then the bias introduced by endogeneity is very much reduced. For example D'Costa et al. (2013) do not control for endogeneity, and by not doing so treat their place based agglomeration elasticities as upper bounds.

It is hard to say how the productivity differentials from a new study that met current state-of-the-art practices would differ from those in TAG. This is because the different improvements work in different directions. An individual fixed effects estimation would be expected to lower the differentials, but using nominal wages rather than real wages would increase the differentials. Controlling for endogeneity would lower the differentials too.

Before discussing the derivation of new productivity differentials it is worth contrasting the findings from Dargay et al. (2008) with those presented in Gibbons et al. (2014). Gibbons et al. (2014) attempt to explain how place contributes to individual wages, and use the same dataset as Dargay et al. (2008). They do not report resultant differentials across regions (they also use larger travel to work areas as their geographical disaggregation – so one might expect their differentials to be smaller than would be found at an LAD level). The overwhelming amount of variation in their results stems from individual level characteristics: between 85% and 88% of individual wage disparities are explained by individual characteristics (including individual fixed effects) (Bosquet and Overman, 2019). Area effects account for 6% of individual wage variation (in their simplest wage equation). In their more sophisticated estimations this drops to between 0.1% and 0.9%. This low contribution of area effects to individual wage variation does not mean that there is not residual and possibly statistically significant variation in regional level productivity. What it says is that individuals' characteristics make up the vast majority of the determinants of an individuals' wage. Put another way, the reported regional differentials in the Dargay et al. (2008) work do not exclude the possibility that the variation in the source data of individual wages was driven by individual level characteristics. This can also be seen to an extent in Gibbons et al. (2014 Table 2), as they also present a breakdown of area level wage disparities and find between 1% and 10% of this can be attributed to area effects.

Putting to one side the differences in the econometric methods and zonal differences between the studies we do not therefore see that the two studies are inconsistent.

7.2.2 Disaggregation

Regarding their level of disaggregation the TAG productivity differentials are only disaggregated to the LAD level. This is relatively coarsely defined, against our benchmark level set out in section §7.1.2. In terms of disaggregating these differentials further this is unlikely to have been successful empirically. This is because with only a third of the productivity differentials statistically significant, higher levels of disaggregation would become difficult if one wished to obtain statistically significant results.

7.3 Recommendations for the development of new productivity differentials

7.3.1 Model estimation

The above discussion highlights a number of empirical issues associated with the TAG productivity differentials. In our view if Dargay et al. (2008) was repeated today, it is unlikely its findings would be viewed as sufficiently robust to include in TAG. In some ways Dargay et al. (2008) is contemporary with the first set of agglomeration elasticities the Department used – based on Graham (2007a). Since then the Department has commissioned two research studies into new agglomeration elasticities. The first reported in 2009 (Graham et al., 2009) and is the basis of the current guidance, and the second is currently ongoing. If this was not sufficient reason to update the productivity differentials in TAG, then the insufficient level of disaggregation of the differentials for current appraisal applications is.

The difficulty in recommending an update to the values is an assessment as to how empirically successful such an update would be. The ASHE dataset used by Dargay et al. (2008) gives the largest geographic scope. However, the need to use fixed effects to control for unobserved individual skills would mean that only those workers who move between locations provide the data needed to estimate the productivity effects associated with locations. It is unlikely therefore unlikely that it will be possible to recover statistically significant parameters for the LADs, let alone disaggregating them further – noting that only just over a third of the LAD productivity differentials recovered by Dargay et al. (2008) were statistically significant. Of course until such an approach is attempted one cannot be sure that this will be unsuccessful, but it strikes us as challenging.

The alternative is to use or estimate an econometric model for Great Britain and then synthesise the productivity differentials. Ideally this econometric model needs to be able to:

(1) Give an estimate of productivity endowments in each location; and
(2) Identify how productivity varies with agglomeration.

Arguably the main determinant in how productivity varies by location in Great Britain arises from variations in agglomeration. Whilst endowments in relation to the natural environment vary substantially in the UK, industries such as farming that utilise these natural endowments form only a small part of the economy. Other types of endowments such as institutions, regulatory frameworks and access to finance will be fairly similar across most of Britain. For France, Combes et al. (2008) found that the effect of endowments on regional productivity differences was small, with the majority of the differences arising through agglomeration. A well estimated agglomeration model would therefore be essential to any synthetisation of locational productivity differences.

On this basis the way forward would either be to use an existing empirical model or to estimate a new model. There is also a consistency argument that would suggest ensuring the agglomeration model is consistent with that used in TAG for the estimation of agglomeration impacts. This is particularly relevant as dynamic clustering impacts will be estimated using the TAG agglomeration elasticities, whilst the M2MLPJ effects are estimated using the productivity differentials.

1. **Existing Model.** There are two options here:
   a. The Graham et al. (2009) model upon which the existing TAG elasticities are based (though this is now ten years old and does not address the endogeneity problem), or
   b. The model currently being estimated by Cambridge Econometrics for the DfT should this be adopted by DfT in TAG.

   The pros for using one or other of these models would be consistency with the TAG parameters for agglomeration. There would also be only a limited amount of additional research necessary. The cons of using one of these models is that the level of disaggregation will be limited to that of the agglomeration studies – which in the case of Graham et al. (2009) is by industry – and are unlikely to include endowment related productivity impacts. Additionally, for M2MLPJ we are interested in differences in labour productivity and not total factor productivity (TFP). The Graham et al. (2009) work is based on TFP. We have not had sight of the Cambridge Econometrics work and cannot therefore offer an opinion on the minimum level of disaggregation possible, nor whether it is possible to separate labour productivity changes from TFP changes. The risks of using an existing model would be small, as one model already exists and is regarded as robust albeit with some limitations.

TABLE 7-1: POTENTIAL EARNINGS DATASETS

	Sample Size	Panel element	Earnings data	Workplace geographic disaggregation	Employee personal characteristics	Employee job characteristics	Firm characteristics
Labour Force Survey (LFS) is a study of the employment circumstances of the UK population. It is the largest household study in the UK and provides the official measures of employment and unemployment.	35,000 per quarter	Each household is interviewed every quarter for five quarters (i.e. the panel covers 1.25 years)	Good – hourly wage per employee	Good – LAD (obtainable under special licence or at Virtual Microdata Laboratory)	Good – gender, qualifications, age, ethnicity, LAD of residence	Good – occupation, shift work, annual leave, pension, self-employed, temp or permanent, overtime, years employed	Weak – industrial classification, size of workplace, public/private
Annual Survey of Hours and Earnings (ASHE) is the most comprehensive source of information on the structure and distribution of earnings in the UK. ASHE provides information about the levels, distribution and make-up of earnings and paid hours worked for employees in all industries and occupations.	1% random sample of PAYE workforce. Currently approx. 180,000 employees per annum.	Aside from retirees and new entries to the labour market ASHE is a panel dataset.	Good – hourly wage per employee	Good – LAD, travel to work areas, parliamentary constituency (obtainable at Virtual Microdata Laboratory)	Weak – gender, age, LAD of residence	Good – occupation, shift work, annual leave, pension, self-employed, temp or permanent, overtime, years employed	Weak – industrial classification, size of workplace, public/private
Monthly Wages and Salaries Survey (MWSS) collects monthly information on wages and salaries of businesses in Great Britain. It forms the basis of the Average Weekly Earnings (AWE), which is used to measure the increase of wages over time.	9,000 businesses covering 13.8 million employees	All businesses with > 1,000 employees. Businesses < 1,000 employees only participate for a fixed period.	Weak - Total wage bill for company with breakdown for holiday, bonuses, overtime etc.	Good - LAD	Weak – no data	Weak – no data	Weak – industrial classification, size of workplace, public/private

Source: Dargay et al. (2008); Office for National Statistics (ONS) (2019)

2. **New model:** A new model could be developed based on the ASHE dataset – i.e. be based on differences in labour productivity as measured by the wage. Of the three recognised ONS labour market datasets (see Table 7-1), ASHE is likely the best. It has a good coverage at a disaggregate level, and is also a panel dataset. This model could use a state of the art agglomeration estimation in combination with very aggregate zoning system (e.g. Government Office Regions) – the latter to reflect broad differences in endowments. The advantages (pros) of estimating a new model would be that it would directly identify variations in labour productivity including individual based effects, and it could be disaggregated to a level suitable for M2MLPJ use. It might also be able to reflect some of the productivity differences due to endowments – albeit at a likely very broad/regional level. The disadvantages are that the agglomeration elasticities from the model (and therefore the productivity differentials) would not be fully consistent with the elasticities in the agglomeration part of TAG. There are also significant risks associated with the level of robustness that can be achieved in any new model estimation in this field.

   Additionally, as we are interested in the marginal product of labour (MPL) there may be a need to test the model estimated to the inclusion of non-wage labour costs such as maternity leave, annual leave, employers national insurance and company pension contributions. These non-wage labour costs should be included in any estimate of the MPL.[25]

   There also exists a debate regarding whether labour markets are imperfect at lower wage levels (see e.g. Card and Krueger, 2000). This would mean that the wage is not always representative of the MPL. Testing the model to the inclusion or exclusion of low skilled workers who arguably face imperfect labour markets may therefore also be necessary.

7.3.2 Implementation in TAG

Derivation of productivity differentials

We could envisage that a strategy comparable to that of the value of travel time savings could be used to implement the output from the resultant model estimation in TAG. With the VTTS research an econometric model was developed, which was then applied to produce the standard values that are published in TAG (Unit A1.3). The VTTS model itself is made available in the variable demand modelling note (Unit M2).

Borrowing from this approach, standard productivity differentials by LAD by industry could be published in TAG for like for like job moves. Providing the econometric model would then allow

[25] Non wage labour costs are utilised in addition to wage date for estimates of employers business VTTS that are estimated using the cost saving method (e.g. HGV drivers).

stakeholders to calculate more nuanced productivity differentials should their projects warrant it (e.g. by location within the LAD – suburbs versus city centres – or by forecast year).

Our suggestion is that the empirical model is applied to a dataset of employment by LAD by industrial sector and a matrix of transport costs by forecast year. This would then give a set of wage estimates by forecast year by LAD by industrial sector. From this set of estimates productivity differentials relative to the average wage in GB could be derived by industrial sector. TAG Could then publish something similar to Table 7-2 for each forecast year.

TABLE 7-2: EXAMPLE FORMAT FOR TAG PRODUCTIVITY DIFFERENTIALS

LAD_code	LAD_name	Index of Productivity per Worker by sector $PI_{i,s}$ relative to average worker productivity in GB 2020			
		Manufacturing	Construction	Consumer services	Producer services
XXXXX	LAD A	0.1150	0.0840	0.1500	0.2500
YYYYY	LAD B	0.1000	0.0630	0.1100	0.1200

NB: Numbers are for illustrative purposes only. In this hypothetical example both LAD A and LAD B have higher productivity relative to the average LAD, with LAD A having the highest productivity. The productivity differential between A and B is largest for producer services.

It would be necessary to also publish in TAG the methodology used to derive the productivity differentials, so that if a more nuanced zoning system than LADs was required by stakeholders (e.g. to distinguish between moves between city centres and suburbs), then productivity differentials for that zoning system could be derived in a manner consistent with the TAG LAD ones.

TAG Wider Impact Equations

The TAG equations do not need adapting substantially from those currently in TAG. An adjustment is needed from GDP to wages, and an adjustment is needed for productivity differentials by forecast year *f*, and by industrial sector *s*. This gives the following equation:

$$\Delta \mathrm{WAGE}^{A,f} = \overline{\mathrm{WAGE}}^{\mathrm{B,f}} \sum_{i,s} \left(E_{i,s}^{\mathrm{A,f}} - E_{i,s}^{B,\mathrm{f}} \right) \mathrm{PI}_{i,s}^{f} \qquad \text{Equation 19}$$

Where:

$E^{\mathrm{A,f}}$ is the total employment by sector *s* for each area i in the base *B* and alternative *A* case in forecast year f.

$\mathrm{PI}_{i,s}^{f}$ is the zonal productivity differential per worker in sector *s* in each area *i* in forecast year *f*.

$\overline{\text{WAGE}}^{\text{B,f}}$ is the national average wage per worker in the base case *B*. This will vary depending on the forecast year *f*. This assumes workers that move are average for their sector. See note below.

$\Delta\text{WAGE}^{A,f}$ Is the movement to more/less productive jobs impact on wages of the alternative case (*A*) compared with the base (*B*), to be calculated. This will vary depending on the forecast year f.

The wider impact equation in TAG would then become:

$$\text{WI2}^{\text{f}} = \tau_1 \, \Delta\text{WAGE}^{A,f} \qquad \text{Equation 20}$$

Where:

τ_1 Is the marginal tax rate on earnings.

Note these equations assume that the workers that move have average productivity for that industrial sector within that region, and in the new region have the average productivity for that sector within that region. If it is considered that the workers that move are not 'average' and are at one or other end of the productivity distribution for that industrial sector, the $\overline{\text{WAGE}}^{\text{B,f}}$ will need to be adjusted to be more representative of their productivity.

Hypothetical examples

To illustrate the applications of these equations we now apply them for two move to less productive jobs scenarios with average (median) earnings of £22,500 (see Table 5-1):

Scenario 1: Like for like job moves. 500 producer services jobs move from Region A (high productivity) to Region B (lower productivity). Originally there are 30,000 producer services jobs in Region A, and 5,000 in Region B.

$$\Delta\text{WAGE}^{A,f} = £22{,}500 * [(29{,}500 - 30{,}000) * 0.2500 + (5{,}500 - 5{,}000) * 0.1200]$$

$$= £22{,}500 * [-125 + 60]$$

$$= -£1{,}462{,}500$$

With τ_1, the marginal tax rate on earnings, at 45.8% [26].

[26] From income tax at 20%, employees NI at 12%, employers NI at 13.8%, based on annual earnings of £22,500

$$\mathrm{WI2^f} = \tau_1 \, \Delta\mathrm{WAGE}^{A,f}$$

$$= 0.458 * -£1{,}462{,}500$$

$$= -£0.670\mathrm{M}$$

Note: dynamic clustering benefits/dis-benefits arising through M2MLPJ would be in addition to the WI2 wider impact.

Scenario 2: Moves between region and industrial sector. 500 consumer services jobs move from Region A (high productivity) to manufacturing jobs in Region B (lower productivity). Originally there are 30,000 consumer services jobs in Region A, and 5,000 manufacturing jobs in Region B.

$$\Delta\mathrm{WAGE}^{A,f} = £22{,}500 * [(29{,}500 - 30{,}000) * 0.1500 + (5{,}500 - 5{,}000) * 0.1000]$$

$$= £22{,}500 * [-75 + 50]$$

$$= -£562{,}500$$

With τ_1, the marginal tax rate on earnings, at 45.8%[27].

$$\mathrm{WI2^f} = \tau_1 \, \Delta\mathrm{WAGE}^{A,f}$$

$$= 0.458 * -£562{,}500$$

$$= -£0.256\mathrm{M}$$

Note: dynamic clustering benefits/dis-benefits arising through M2MLPJ would be in addition to the WI2 wider impact.

[27] Based on a marginal change in annual earnings of £22,500 where income tax at 20%, employees NI at 12%, employers NI at 13.8% is applicable.

8 CONCLUSIONS

8.1 The research objectives re-visited

We are now in a position to return to the research objectives and questions posed by the Department for Transport. In an economy in a spatial equilibrium there are mobile households and firms in both low and high productivity locations. In terms of choice of location, firms balance productivity, factor costs and transport costs. Households in contrast balance income and quality of life including the cost of living and housing. In equilibrium neither firms or households can move location without making themselves worse off.

Research Objective 1: *What are the drivers for workers to move to a more/less productive region?*

A regional transport investment increases productivity and attracts mobile activity to that region. This is because the transport investment reduces transport user costs including the time spent travelling – giving improvements in the locational efficiency of the region – and increases the amount of capital in the region. Both of these raise regional productivity. Where this increase in economic activity interacts with agglomeration economies a process of cumulative-causation can be initiated further raising the economic activity of the region.

An inter-regional transport investment can trigger a move to either a more or less productive region depending on the context. In a country such as the UK with a mature transport network where transport costs are already relatively low, an inter-regional transport investment could lead to a dispersion of economic activity form the core to the periphery. This would be the case for industries where the centrifugal forces to geographic concentration (specifically land rents and dis-economies of scale) outweigh the centripetal forces (market size effects, thick labour markets and pure external economies). Manufacturing has been found to disperse, and there is some evidence that some services have dispersed in response to transport investments. The tension between the centripetal and centrifugal forces implies that there are variable returns to agglomeration. We would expect these to vary by industry.

Effective modelling of these drivers therefore requires a good model of how transport user costs will vary, but also of what the benefits of agglomerating are.

The empirical literature shows significant positive productivity effects of transport investment, though the effects in countries with developed transport networks are much smaller now than they used to be. We also see significant evidence of the displacement effects of transport investments. The effects are quite heterogenous, with only some transport intensive sectors experiencing significant benefits from transport investment, and even then these sectors varying with the type of transport investment. There remain limitations to the empirical literature, with a lot of it being associated with the construction of new networks in the US and China, but also in that there appears to be little evidence on the role transport investment may have in dispersing economic activity from the core to the periphery, as would be predicted by new economic geography models. There is also little on the micro-behaviour of firms that do ‘move’.

With respect to household behaviour we might expect changes in commuting, household location and the supply of labour. There is evidence on all these aspects of behaviour stemming from a transport investment. However, this evidence is not sufficiently detailed to be able to quantify the proportion of re-located jobs is that is taken by inter-regional commuters, increases in local labour supply or workers who have migrated between regions. This is an evidence gap.

Finally, the empirical literature also emphasises that a number of pre-conditions are necessary for a transport investment to have a positive impact on the economy. If these pre-conditions are not met, then the drivers of user benefits, agglomeration economies and an increase in transport capital stock will have limited impact on business location and investment decisions.

Research Objective 2: *What is the value of output created in a lower productivity region, from a firm or worker previously located in a higher productivity locality?*

The value of a transport investment that moves production from one region to another is the sum of the transport user benefits and other associated elements in a transport cost benefit analysis, plus any additional surpluses (deficits) that are created from the existence of market failures such as taxation. Whilst in the main a lot of government taxation is distortionary with respect to the M2MLPJ household choices are distorted by the tax system – by the tax on the supply of labour – whilst firm choices are not distorted by corporation tax. Of course, this conclusion is based on a simple model and the taxation system is far more complex, but this is our broad conclusion.

The implication of this is that wider impacts from M2MLPJ will only occur through changes in commuting patterns or net changes in the distribution of population between regions. The analysis that supports the M2MLPJ must explain why labour demand changes and the extent to which labour supply is provided via the mechanisms of change from sectoral change, labour market participation, commuting or inward migration. When unemployment is high labour demand may also be met through a reduction in unemployment. It is also essential that the estimates of changes in employment and population in affected localities are full long-run changes, taking into account adjustment in the local labour market (e.g. changes in employment in existing local firms) and, where appropriate, changes in the housing stock associated with movement of workers.

Given that TAG guidance calculates the Wider Impact of a M2MLPJ using GDP/worker and marginal tax rates based on all forms of government taxation, this strikes us as an error. The value of a M2MLPJ should be based on earnings and the marginal rate of income tax (on earnings).

In the case of a movement of output from a high productivity region to a low productivity region, the additionality would be negative (i.e. a deficit), as the amount of income tax generated will decrease with the reduction in labour productivity. This adjustment is correct. Furthermore, it is realistic for a firm to move production to a low productivity region in response to a transport investment when selling at a world price. This is because the choice of location is a function of both productivity (including market access/transport costs) and factor costs, and if any one of these changes then economic activity will shift.

There is a strong inter-relationship between the M2MLPJ wider impact and the wider impacts associated with dynamic clustering and changes in labour supply. It is therefore important that consistency between these wider impacts is maintained in TAG. At the moment inconsistencies arise in the treatment of the marginal rates of tax and the use of a productivity dampening factor (between M2MLPJ and labour supply) and in the productivity differentials arising from agglomeration (between M2MLPJ and dynamic clustering).

Other market failures may exist in the lower productivity region where economic activity expands e.g. in the labour market or in the land market. Any wider impacts associated with these should also be captured in the appraisal. A number of these may be difficult to parameterise, but in our opinion those that can be should be enumerated as far as possible.

***Research Objective 3**: To review the rationale for output per worker being valued lower in areas with low productivity even though the market price of the good is common across all areas.*

Our consideration of how GDP changes as a result of a M2MLPJ is that it is context dependent. GDP can go down – even when selling at a world price. A simple scenario we considered with equivalent demand and supply conditions in both regions suggested a reduction in GDP driven by the differences in wages between the two regions triggered by a transport intervention. In that case households were exchanging a welfare benefit (e.g. from lower commute costs or improved amenities) from moving regions with a reduction in income. This effect reduces GDP – even though welfare is increasing. However, our analysis indicated that the size and sign of the GDP change is context dependent, and therefore difficult to predict *a priori*.

Furthermore, current TAG guidance suggests that with a M2MLPJ GDP will change in line with productivity differentials. This is unlikely to occur in all scenarios. This context dependency means that it is hard to give firm guidance on how to predict changes in GDP due to the M2MLPJ. Our view therefore is that changes in GDP arising from M2MLPJ should be estimated in a model of the economy – or as TAG terms them a Supplementary Economic Model.

In the course of reviewing TAG M2MLPJ guidance it was also identified that the productivity differentials in TAG are applied incorrectly – as they are elasticities and not factors.

***Research Objective 4**: To review the robustness of the productivity differential data contained in TAG.*

Our view is that the productivity differentials in TAG are weak by today's standards. This is because, by today's standards, the estimation method did not effectively control for individual skills, it included an adjustment to the wage for regional price variations and did not use nominal wages, three years of data from the same workers was pooled which would inflate the levels of significance, and it did not control for endogeneity. From a practical appraisal perspective the productivity differentials are also weak as they are not sufficiently disaggregated – there being only one productivity differential for each LAD.

In our view it would be very challenging to estimate a new robust set of productivity differentials that are sufficiently disaggregated. Our suggestion would be to use a model to predict the

productivity differentials at the desired level of disaggregation. This model could either be an existing model or a new model estimated specifically for the purpose.

The advantage with using an existing model, such as that used to give the agglomeration elasticities, is achieving consistency across different parts of TAG. The disadvantage would be that an existing model may be focused on total factor productivity differentials and not labour productivity differentials (as are required here), may not be sufficiently disaggregated and may not capture any differences in productivity due to endowments. An estimation of a new model would be more resource intensive and would carry with it risks of not being able to recover any robust parameters. It would also mean that there would not be consistency between the agglomeration parameters in TAG and the M2MLPJ parameters. The advantage of a new model estimation though would be that it could be specifically targeted at the requirements of M2MLPJ.

8.2 Recommendations and further research

Broadly speaking our conclusions re-affirmed that a move to more or less productive jobs will lead to a wider impact if productivity differences exist between localities and these interact with market failures. This is consistent with TAG. This wider impact specifically relates to a distortion caused by income taxation in the decision as to where to locate and is a function of productivity differences. There may be other market failures that become relevant when jobs re-locate, but these are not directly related to the choice of location nor are directly productivity related. Subject to context, they could include: the standard TAG ones of imperfect competition (income tax, static and dynamic clustering), as well as those associated with the land market, those giving rise to structural unemployment, those associated with knowledge spillovers (from inward investment), and any associated with corporation tax (if it impacts on investment rates).

Our review of TAG would suggest that the manner that M2MLPJis implemented in TAG needs to be re-visited and updated. As mentioned above, M2MLPJ is closely related to a number of other wider impacts and the inter-relationship between these also needs to be reviewed. We have separated the recommendations into short (within a year), and medium term (within five years) options.

Short term

1. Update the current differentials in TAG to be percentage differences, so they are consistent with how they are applied in the TAG equations. The current values in the wider impacts dataset are sourced from the coefficients (β) of the regression model. To convert these to percentage differences the following transformation should be applied to them: $e^{\beta}-1$.
2. Update equations in TAG to be in terms of wages and not GDP. This will require additional research/reviews to:
    a. Update the marginal tax parameter τ_1 to relate to earnings only.
    b. Consider the role as to whether TAG should give guidance on how to predict GDP change from M2MLPJ. If so, additional research may need to be commissioned to advise on this.

3. Ensure TAG is clear that M2MLPJ is only relevant when there is displacement in employment from one region to another, with no net change in employment at the UK level. Changes in specialisation which lead to employment shifts between industries in a region do not generate an M2MLPJ wider impact.

Medium Term

4. Commission research to develop new productivity differential parameters for TAG based on either the transfer of an existing econometric model or the development of a new model. There are pros and cons to each alternative.
5. Review the inter-relationship between M2MLPJ wider impact and the wider impacts of (a) labour supply, (b) dynamic clustering and (c) agglomeration in TAG to ensure consistency in treatment across the wider impacts. There is a strong inter-relationship between these wider impacts: changes in labour supply are one of the mechanisms by which M2MLPJ can come about, M2MLPJ is the source of dynamic clustering, whilst the productivity impacts due to agglomeration are the primary source of the productivity differentials in M2MLPJ. Ideally some parameters should be common, or come from the same source, across these wider impacts, to ensure consistency.
6. M2MLPJ is concerned with changes in land use. Due to difficulties in calculating user benefits when land uses change, arising from amongst other things measuring changes in zonal attractiveness, it is currently difficult to obtain a complete measure of total economic impact when M2MLPJ is applicable. Addressing this knowledge gap is therefore important for such projects.
7. There is an evidence gap in the empirical evidence that supports M2MLPJ. In particular there appears to be little evidence on the role transport investment may have in dispersing economic activity from the core to the periphery, as would be predicted by new economic geography models. There is also little on the micro-behaviour of firms that do 'move', and with respect to households the evidence is not sufficiently detailed to be able to quantify the proportion of re-located jobs that is taken by inter-regional commuters, increases in local labour supply or workers who have migrated between regions. Address these evidence gaps are an area of future research, and would be useful in understanding the expected scale of any M2MLPJ.
8. Wider impacts other than those mentioned earlier may also be relevant for projects where M2MLPJ wider impacts are calculated. These may for example include unemployment impacts, or impacts associated with re-balancing the economy. The wider impacts for which guidance is produced should be reviewed, with consideration given as to whether the range should be broadened. This may then lead to the commissioning of longer term research projects to parameterise any 'new' wider impacts.

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ANNEX A: SECTION 4.2.2: MOVING WORKERS AND MOVING JOBS

Region 1 has fixed productivity and wages, $q_1 = w_1$, and fixed house prices (infinitely elastic supply at constant marginal cost), p_1. Region 2 has L_2 workers producing output $q_2F(L_2)$, hence wage $w_2 = q_2F'(L_2)$, and housing supply curve $H_2 = S(p_2)$. Equilibrium conditions are full employment $\bar{L} = L_1 + L_2$, each worker consuming one unit of housing so $L_i = H_i$, and workers indifferent between location $(1-\theta)w_1 - p_1 = (1-\theta)w_2 - p_2$.

If functional forms are iso-elastic then:

Output in region 2, $q_2F(L_2) = q_2L_2^{1-\frac{1}{\eta}}\eta/(\eta-1)$, and labour demand curve $L_2 = (w_2/q_2)^{-\eta}$, $\eta > 1$.

Cost of producing housing, $B(H_2) = b_2H_2^{1+\frac{1}{\varepsilon}}\varepsilon/(\varepsilon+1)$, so inverse supply curve $b_iH_i^{\frac{1}{\varepsilon}} = p_i$.

Proportionate changes are denoted ^. Following exogenous change $\hat{q}_2$ endogenous variables change according to:

$$\hat{H}_2 = \hat{L}_2 = \varepsilon\eta\hat{q}_2/(\varepsilon+\eta s), \qquad \hat{p}_2 = \eta\hat{q}_2/(\varepsilon+\eta s), \qquad \hat{w}_2 = \eta s\hat{q}_2/(\varepsilon+\eta s),$$

where the share of housing in household expenditure is defined as s, so, $\hat{p}_2 s = \hat{w}_2$.

Thus, if the supply of housing is perfectly inelastic, there is no population movement, and all new labour demand is met by displacement.

Valuation: Real income is the value of output produced minus the cost of housing provision,

$$W = (q_1 - p_1)L_1 + q_2F(L_2) - B(H_2)$$

Differentiating and using equilibrium condition $(1-\theta)w - p_1 = (1-\theta)w_2 - p_2$,

$$dW = (q_1 - p_1)(-dL_2) + (w_2 - p_2)dL_2 + F(L_2)dq_2 = \theta(w_2 - w_1)dL_2 + F(L_2)dq_2.$$

ANNEX B: EXTRACT FROM TAG UNIT A2.3 EMPLOYMENT EFFECTS GUIDANCE

Extract from Section 3.3 pp12-15 in Department for Transport (2018b)

5.3 Quantifying and Valuing the Move to More/Less Productive Jobs

3.3.1 The move to more/less productive jobs arises from the relocation of employment and the spatial inequality of productivity (*place-based effects).* This sub-section provides guidance to forecast employment changes and estimate the GDP and welfare associated with any productivity changes.

3.3.2 As noted in paragraph 2.2.12 even in instances of 100% displacement, in which economic activity relocates, such that one area gains at another's expense, there may still be a net national productivity impact and change in welfare, as a result of place based effects. The methodology presented in this sub-section explicitly takes account of displacement in the estimation of the productivity impact and welfare change:

- Quantification – there is no employment increase, the increase in jobs in any one area must be matched by an equivalent reduction in other areas; and
- Valuation – only the output change as a result of productivity impacts is estimated. This is done through the application of productivity differentials (equation 5).

3.3.3 Care should be taken when valuing the productivity impacts, as the productivity differentials could potentially lead to misleading results (see paragraphs 2.2.15 for more details). If the use of the valuation methodology from this guidance is considered to produce misleading results, this should be explained in the Economic Narrative and an alternative method proposed and justified – see M5.3 for the principles which should be adopted when using Supplementary Economy Models. If a supplementary method is used, the results should be reported as an indicative monetised impact.

3.3.4 Dynamic Clustering (TAG Unit 2.4) is related to the move to more/less productive Jobs, as the relocation of employment can affect the physical density of clusters. However, for both

impacts to be included in the analysis they should be individually identified and justified in the Economic Narrative.

5.3.1 Quantifying the Move to More/Less Productive Jobs

3.3.5 The relocation of employment can be quantified either (a) using scenarios about how firms and households are likely to respond to the transport improvement or (b) using a land-use model to forecast how the transport scheme would impact firms and households. Any scenarios should be evidence based with the treatment of displacement made clear and consistent with the appraisal of dynamic clustering impacts.

3.3.6 To ensure consistency between the forecast generalised travel costs and the location of employment, there should be an interaction between the methodology to forecast land use change and the transport model. In other words the outputs from the transport model should be used to forecast the land use change, and the subsequent land use forecast should serve as a further input to the transport model. In this manner employment locations are informed by generalised travel costs and the generalised travel costs by employment locations.

3.3.7 If dynamic clustering has also been identified as a potential impact of the transport investment in the Economic Narrative, this should be estimated using the same forecast of employment relocation as for the move to more/less productive jobs.

5.3.2 Valuing the Move to More/Less Productive Jobs

3.3.8 The valuation of the move to more/less productive jobs resulting from a scheme can be calculated in terms of GDP impacts from equation 5 below. The associated welfare change, which is additional to user benefits, is equivalent to the benefits to the exchequer. These are the tax revenues resulting from changes in productivity and can be estimated as 30% of the resultant change in GDP. This tax revenue impact is calculated below in equation 6. This reflects the increase in tax revenue (income tax, national insurance contributions and corporation tax).

3.3.9 There are a number of assumptions underlying the methodology for valuing the move to more/less productive jobs:

- First, the productivity change is a function of the average productivity differential of each area, gaining and shedding employment, from the national average.
- Second, the output change associated with changes in productivity is valued by GDP per worker, which implies a change in the return to labour and capital.

The geographical distribution of demand and supply of labour will be a function of profits and wages respectively. Thus productivity changes, which result from the relocation of employment, will be associated with wage and profit changes. For this reason the move to more/less productive jobs are valued using GDP per worker.

- Third, private benefits to employees and employers who are relocating to more productive jobs are captured by the change in transport user benefits. However the method for valuing move to more/less productive jobs implies land use change. Where there are significant feedback effects from land use change the methodology to value user-benefits, rule of a half, breaks down. While the evidence base needs to be developed further, the estimation of user-benefits with fixed land use may provide a reasonable proxy for user-benfits with variable land use, capturing the welfare effects of most changes in the transport market.
- Fourth, the welfare change associated with the move to more/less productive jobs is equal to the change in tax revenue.

Equation 5 GDP Impact	
$$GDP^{A,f} = GDPW^{B,f} \sum (E_i{}^{A,f} - E_i{}^{B,f}) PI_i$$	
$E_i{}^s$	is the total employment for each area *i* in the base *B* and alternative *A* case.
PI_i	is the zonal productivity differential per worker in each area *i*. Technological progress is assumed constant so this will not vary by forecast year.
$GDP^{A,f}$	Is the movement to more/less productive jobs impact of the alternative case (A) compared with the base (B), to be calculated. This will vary depending on the forecast year f.
$GDPW^{B,f}$	is the national average GDP per worker in the base case *B*. This will vary depending on the forecast year *f,* is taken from the Wider Impacts Dataset.

Equation 6 Wider Impacts Tax Revenue	
$$WI2^f = \tau_1 \, GDP^{A,f}$$	
$WI2^f$	is the welfare associated with the move to more/less productive jobs and will vary depending on the forecast year f.
τ_1	Is the tax take on the move to more/less productive jobs, currently estimated to be equal to 30%.[28] The tax take will not vary depending on forecast year.

5.3.3 Checklist for appraising the Move to More/Less Productive Jobs

3.3.10 The table below provides a checklist of the key evidence requirements when appraising the move to more/less productive jobs.

[28] Estimated tax take of GDP changes from existing workers becoming more/less productive and hence attracting a marginal income tax as well as an increased operating surplus.

Table 1 Checklist for appraising the move to more/less productive jobs	
Issues	**Check**
Provide context-specific evidence that a change in transport accessibility will lead to a relocation of economic activity	
Estimate change in GTC resulting from transport scheme	
Estimate relocation of jobs and change in productivity resulting from transport scheme	
Estimate tax wedge associated with increased GDP	

3.3.11 Having quantified and valued the move to more/less productive jobs resulting from a transport investment these impacts should be reported appropriately – see section 4 for information on documenting analysis and reporting results within the Transport Business Case.

ANNEX D: KEY STUDIES UNDERPINNING EVIDENCE FOR M2MLPJ

Study	Key findings in relation to M2MLPJ study (NB papers may have other key findings)	Additional comments
Transport investment and productivity – results in aggregate		
Aschauer (1989)	0.24 output elasticity to core infrastructure (including transport). Implied public capital investment very important for productivity growth.	Sparked a large literature studying the productivity impacts of public sector capital investment. Flaws in the econometrics leads to his findings now being unconsidered unreasonably high.
Melo et al. (2013)	Average elasticity of output to transport infrastructure is 0.06 from meta-analysis.	Meta-analysis includes early studies, with arguably too high estimates, implying this average is too high.
Holmgren and Merkel (2017)	Meta-analysis. Highest precision in output elasticities is from those close to zero. Calls into question the robustness of high elasticities.	Output elasticities are highly dependent on the econometric method with predicted values from meta-analysis for different econometric methods ranging from 0.06 to 0.4.
Jiwattanakulpaisarn et al. (2012)	Marginal productivity gains from further expansions of US road network are positive but trivial.	
General conclusions	*Transport investment has observable productivity impacts, but these are much smaller than were first thought. Econometric work is challenging, and the largest differences between studies is due to methods.*	
Transport investment and productivity – transport mode and industry sector differences		
Fernald (1999)	Vehicle intensive industries received the largest productivity increase from the construction of the US inter-state highway network (US data)	
Duranton et al. (2014)	Cities with larger amounts of highways specialise in manufacturing (US data)	
Lin (2017)	HSR benefits tourism and industries requiring cognitive and non-repetitive tasks. Road investments benefit non-service sector industries. (Chinese data).	
Holmgren and Merkel (2017)	Meta-analysis indicates differences in mode and sectoral output elasticities. Investing in airport infrastructure is expected to have a lower effect for manufacturing and construction output than investing in roads. Whilst for service and agricultural sectors, investing in air infrastructure has a higher effect than investing in roads. Investing in rail appears to have a higher impact than investing in roads for the service sector but not for other sectors. Investments in port	Agricultural results may seem surprising, but important to recognise these are international studies. Internationally, air transport is relevant for the export of perishable products. Port infrastructure is also very important for the export of dry bulk goods such as grains and forestry.

Study	Key findings in relation to M2MLPJ study (NB papers may have other key findings)	Additional comments
	infrastructure have a higher estimated effect on production for the agricultural sector than investments in road. (International data)	
Gibbons and Wu (2017)	Air transport infrastructure has significant productivity impact on manufacturing firms, but no observable effect on service sector. (Chinese data)	Possible explanation for this contrasting industry specific effect of air travel with other studies is the role of the supply chain. Manufacturing firms may require international connectivity of all forms to be part of that supply chain – and air is the best way of delivering person related interactions over large distances. China is a large exporter of manufactured goods, but not of services.
Gibbons et al. (2019)	New roads have significant productivity effects on existing firms. They also increase employment and in their vicinity and the number of firms. The largest employment effects are found in producer services, transport (specifically road freight and cargo handling) and in 'other' industries which is a residual category. (UK data)	A plausible interpretation is that new transport infrastructure attracts transport intensive establishments to an area, and also leads to some reorganization of production in existing businesses.
General conclusions	*The key driver to productivity gains is through infrastructure use (i.e. user benefits). Who uses the transport investment is critical to the productivity gains. As different industries use transport infrastructure in different ways and have preference for different types of infrastructure, the productivity impacts vary by mode and industry. Importantly there may be international differences in how transport infrastructure is used, and therefore international differences in the sectoral productivity impacts.*	
Transport investment and displacement		
Rephann and Isserman (1994)	Urban areas and their adjacent counties were the largest beneficiaries of the construction of the US interstate highway network. Rural counties along the interstate highway network gained little. Counties that are not direct beneficiaries of the interstate network and not in an urban fringe, experience many negative effects. (US data)	
Chandra and Thompson (2000)	US inter-state highway network displaced economic activity to 'rural' counties that the network passed through. Activity was displaced from counties that were not connected to the network. (US data). Retail displacement particularly high.	Only considered impact on rural counties.

Study	Key findings in relation to M2MLPJ study (NB papers may have other key findings)	Additional comments
Duranton and Turner (2012)	Investment in the inter-state highway network increased city employment. This is displaced. Elasticity is 0.15. (US data)	
Baum-Snow et al. (In Press.)	In China the highway investment displaces economic activity to 'primate' regional cities from the hinterland including the hinterland cities. A 10% increase in roads within 450 km of a prefecture city reduces non-primate prefecture population by 1.7%, but increases primate prefecture population by 1.1%. (China data)	
Qin (2017)	HSR lines have a negative impact on the counties that they pass through, with activity displaced to the cities which form the nodes of the HSR network. (China data)	Here the counties they pass through invariably have no connection to the HSR network (except via the city nodes).
Lin (2017)	HSR connection increases city employment by 7%. (China data)	The tourism sector and industries which require workers with skills in cognitive and non-repetitive tasks grow the most.
Brueckner (2003)	Increased air traffic increases employment with an elasticity of 0.1. Majority of growth is in the service sector. (US data, metropolitan regions).	Population grows slightly more rapidly than employment.
Sheard (2014)	Contrasts with Brueckner (2003) as finds no effect on total employment with increased airport size. However, agrees with Brueckner (2003) that there is an increase in service sector employment. The implied elasticity of tradable-service employment with respect to airport size is 0.22. (US data, metropolitan regions).	This specialisation effect represents displacement of employment between industries.
Tveter (2017)	Populations in municipalities with small regional airports increased, but the effect is not statistically robust. (Norway data)	
Ahlfeldt and Feddersen (2017)	Worker and firm selection drive the observed change in productivity and output in small towns 'accidently' connected to an HSR network. (Germany data)	'Worker and firm selection' implies high skilled workers and/or firms producing high value added move location (i.e. displacement)
Cheng et al. (2015)	HSR in France has dispersed some service sector activity away from the core (Paris) to cities on the HSR network. (France data)	This is a more qualitative study, and does not employ the rigorous econometric methods used in the other identified studies.
General conclusions	*The evidence indicates that employment, firms, and population will move location in response to a transport investment driven productivity shock. Cities are the main beneficiaries. Unconnected regions lose out. Displacement also leads to regional sectoral change (i.e. a change in specialisation) – as only certain industries gain from the transport investment. Evidence to date is on centralisation of economic activity in response to transport investment;limited evidence for dispersion effects.*	

Study	Key findings in relation to M2MLPJ study (NB papers may have other key findings)	Additional comments
Behaviour of firms – firm re-locations, expansions, new plants and births		
Holl (2004)	Firm births increase in municipalities within 10km of a new motorway, and drop in municipalities more than 10km away (relative to pre-intervention rates). There is however a lot of variation by sector.	A firm birth is defined as a new plant. This could be a re-location, a business expansion, or a 'start-up'.
Baum-Snow (2010).	Expansion of the highway network in cities led to employment (i.e. firms) moving to the suburbs. (US data)	
Baum-Snow et al. (2017)	Urban radial roads and ringroads, and radial railways led to a decentralisation of economic activity (from the city centre to the suburbs). (Chinese data)	
Holl (2016)	Productivity gain from new motorways comes from increased proximity to motorways and agglomeration benefits. 90% of firm re-locations are local, and on average they move the firm closer to the motorway network. Firms that move closer to the motorway network typically have higher levels of productivity. (Spanish manufacturing firms)	
Gibbons et al. (2019)	Incumbent firms re-organise production process to gain productivity gains from new roads. Local employment increases are driven by new firms operating within the area of interest. They imply that these new firms are displacing activity from elsewhere, but do not distinguish whether the firms have re-located or are start-ups which displace activity from incumbents (wherever they are located). (UK data)	
General conclusions	*Limited evidence on the behaviour of firms, but there is sufficient to know that firms do alter behaviour in response to transport investment..*	
Behaviour of households – commuting, migration and labour supply		
De Jong and Gunn (2001), Goodwin et al. (2004), Graham and Glaister (2004), Holmgren (2007), Litman (2019)	Travel demand (person or vehicle kms) is sensitive to changes in travel time and price.	This is a sample of studies demonstrating travel demand (including the demand for commuting) is sensitive to travel time and price changes. They do not specifically refer to changes in commuting behaviour as a consequence of M2MLPJ.
Duranton and Turner (2011).	Changes in the stock of infrastructure increase demand for travel in aggregate.	This will include commuting behaviour, but the paper does not explicitly address commuting.
Baum-Snow (2007b), Baum-Snow (2010),	Expansion of the highway network in cities led to longer commutes (Baum-Snow, 2010), and there is evidence that both households(Baum-Snow, 2007b, Baum-Snow	

Study	Key findings in relation to M2MLPJ study (NB papers may have other key findings)	Additional comments
Baum-Snow et al. (2017).	et al., 2017) and firms move locations (Baum-Snow, 2010, Baum-Snow et al., 2017) as part of the suburbanisation process generated by transport infrastructure. US and Chinese data.	
Holl (2016)	One of the findings is that 90% of firm re-locations are local	If 90% of firm re-locations are local, changes in commuting behaviour are likely to be an important household response to transport infrastructure, particularly if there are frictions in the housing market.
Tveter (2017)	Populations in municipalities with small regional airports increased, but the effect is not statistically robust. (Norway data)	This would be interpreted as migration.
Berechman and Paaswell (2001)	10% improvement in accessibility (predominantly PT), which affects 1000 potential employees, will stimulate 1.23% new labour market entry in these 4 job types. These four job types comprise 35.6% of workforce. (US data)	Implies an employment elasticity of approx. 0.04 (=1.23*10*0.356/100). Interpreted as originating from a labour supply shift interacting with a short term elastic labour demand function yielding an employment change
Ozbay et al. (2006)	Employment elasticities of accessibility (predominantly private) improvements of around 0.05. (US data)	Same approach as above
Johnson et al. (2017)	Employment elasticities of PT accessibility (mainly bus) improvements in England of around 0.02 (UK data)	
General conclusions	*Households do change behaviour via a variety of different responses. Difficult to pinpoint exact magnitudes of the different responses, but commuting and population movement (migration) are likely the most important. Labour supply elasticities are relatively low. The balance between commuting and migration will be context dependent – as it is easiest to commute short distances.*	