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Assessing the wider economy impacts of transport infrastructure investment with an illustrative application to the north-west rail link project in Sydney, Australia.

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TITLE: **Assessing the wider economy impacts of transport infrastructure investment with an illustrative application to the north-west rail link project in Sydney, Australia.**

ABSTRACT: This paper identifies the employment agglomeration impact of transport investments through a measure of change in effective employment density, using new empirical estimates of the elasticity of productivity with respect to effective density in order to calculate the uplift in benefits (or impact) from this key wider economy impact. The approach combines the behavioural richness of an integrated transport and location choice modelling system (TRESIS) and its outputs to a spatial computable general equilibrium model (SGEM), which uses data at a more aggregate level to compute the additional impacts of transport infrastructure change on the wider economy. This has allowed the development of an integrated transport-location-economy-wide model system known as TRESIS-SGEM. The model system is applied to the introduction of the North-West Rail Link project in Sydney, Australia to illustrate the capability of TRESIS-SGEM, identifying a 17.6% markup over the conventional transport user benefit.

KEY WORDS: ***Wider economy impacts; transport user benefits; employment agglomeration; effective density; spatial general equilibrium; rail projects; Sydney; agglomeration elasticities.***

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1. Introduction

There is a growing interest in identifying the broader set of benefits and costs associated with investment in transport infrastructure that are not accounted for in the traditional set of benefits and costs captured by transport planning models and evaluation frameworks. These extended potential sources are referred to as the wider economy benefits or impacts (WEB or WEI) of transport projects (Joint Transport Research Centre 2008). One of the sources of these benefits[1] is the so-called 'agglomeration' effect (Venables, 2007), often associated with improvements in the transport system. Agglomeration is generally understood to create some economies of scale external to the firm and industry, but internal to a particular urban area (see Graham, 2007b). These economies of scale arise, for example, from the use of an improved public transport network allowing the scale of the market to be increased, firms to share in a larger pool of intermediate inputs, labour inputs, knowledge ('technological spillovers') and other resources. This will result in increased specialisation and improvement in output and labour productivity (for existing as well as new activities); and these improvements can be said to be a source of the WEI of transport projects. The WEIs are not often considered in standard cost benefit analysis because of the usual assumption of constant returns to scale and perfect markets.

To measure the improvement in output and labour productivity following an improvement in the transport network, Venables (2007) used the concept of 'elasticity of output per worker with respect to employment' or 'employment density'[2] (i.e., 'agglomeration elasticity'[3] for short). Agglomeration elasticity measures the extent of the improvement in labour productivity following an increase in 'effective' employment density where the latter is defined, not only in terms of the actual physical employment numbers in various locations, but also in terms of their relative positions with respect to a particular reference point (for example, the CBD). Improvements in a transport system, therefore, can impact on the 'effective' employment density even before or without any of the physical employment numbers changing, provided travel times are used to indicate the relative positions of these employment numbers with respect to the reference point. In practice, however, since travel time is 'endogenous' (it can be affected by the measure of employment density itself through congestion, for example), actual physical distances are used to indicate the relative positions of the physical employment rather than travel time. This leads to the anomalous result that if a transport improvement cannot change physical employment directly (especially in the short run), then also it cannot change effective employment density and therefore cannot impact on productivity. The anomalous interpretation of this result is modified if it is recognised that in the short run and from the point of view of a static *partial* equilibrium analysis, a 'shock' to the transport system is analysed only in terms of its effects on travel behaviour whilst assuming other activities remain the same. However, in a dynamic or long run general equilibrium analysis, the impact of a transport improvement on the economy as a whole is to be considered not only in terms of its effects on travel behaviour (short run), but also on other interrelated decisions (medium and long run) such as housing and employment activities. Therefore, although the immediate or short run impact of a transport project is only on travel times this will bring about other 'adjustments' over time in

[1] Or costs, for example, if benefits (productivity gains) are supposed to be generated by an agglomeration effect, then the opposite of agglomeration (dis-agglomeration) will result in a disappearance of these benefits, i.e. a decline in productivity, and therefore an increase in production costs.

[2] The terms in the square bracket of the equation in the Appendix of Venables (2007) is in fact an aggregation of employment *densities* rather than of employments, using the inverse of the distance function between a location and the centre of the city CBD as weights.

[3] Although Venables (2007) did not use the term 'agglomeration elasticity', it is in fact the same concept as the 'agglomeration elasticity' used by others such as Graham (2007a, b), Mare and Graham (2009) except that in the case of Venables (2007), there is only 'aggregate' or 'effective density' (that of the CBD 'mass') to consider, whereas in the case of others, there are more than one 'effective densities' to consider associated with different 'masses' of different agglomerations in different regions.

other activities such as housing and employment redistribution and the associated physical housing and employment densities. It is through this latter effect that a transport improvement project can cause ‘agglomeration’ or dis-agglomeration in certain locations, and an impact on ‘effective densities’, and therefore impact on labour productivity. To model these effects, however, requires the use of a spatial general equilibrium model, integrated with a transport and land use model, and this is one of the objectives in our study.

The other major objective of our study is to estimate the actual extent of the agglomeration benefits (or dis-agglomeration costs), and therefore the magnitude of the WEIs that follow from a transport investment project for a particular geographical area, namely the Sydney Metropolitan Area (SMA). To do this, we need to estimate the values of the agglomeration elasticities for different employment occupations and different industries situated in this area. Due to data availability limitations for individual firm data, especially for a small geographical area such as the SMA, and the complexity of the estimation task, the estimation of agglomeration elasticities carried out in our study must be considered as preliminary. They are used mainly for the purpose of illustrating the usefulness of our approach rather than for the purpose of specific policy application and should be regarded as illustrative rather than definitive. Nevertheless, when the agglomeration elasticities estimated in this study are compared with other results coming from more exhaustive empirical investigations and based on more extensive spatially disaggregated data, it can be seen that our estimates are within the range of other studies, demonstrating very similar patterns between different industries. So, despite being illustrative, we believe they can be taken with a large degree of confidence, although future studies may want to improve on the accuracy or details of our estimates if improved spatial data in Australia becomes available

The paper is structured as follows. The next section presents the methodology underlying the development of an integrated transport-location-economy-wide model system known as TRESIS-SGEM. This is followed by a section on agglomeration effects in which the model system is used to calculate agglomeration elasticities. The final section applies the model system to the proposed NWRL project in Sydney to identify the mark-up over the conventional transport user benefit to show the importance of including WEI in the economic evaluation of transport infrastructure.

2. Methodology

The challenge in establishing the nature and extent of WEI’s is to recognise the need to embed methods which provide evidence on the full adjustment in the travel market as a consequence of the most meaningful coping or response strategies to new transport investments. This requires a modelling setting incorporating a sufficiently behaviourally rich suite of travel demand and location models, integrated with appropriate feedback and equilibrating mechanisms. Alongside this is the additional need to link the outputs of this to a modelling system that has a framework to identify the wider economy impacts of the specific transport investment under consideration. This latter framework is more commonly known as a spatial computable general equilibrium model (SCGE). In summary, the challenge requires the connecting of modelling at a micro level which must be driven by individual behaviour change to SCGE modelling at a more aggregate (intersectoral and macroeconomic) level to compute the additional impacts of transport infrastructure change on the wider economy.

Although SCGE models have existed for many years, it is only in recent years that serious efforts have been made to connect SCGE models with more micro and behaviourally based transport models. The methodological difficulty arises from linking the two types of models which are based on different theoretical foundations, as well as data availability which are required not only at the micro transport and land-use level but also at the sectoral and economy-wide level with a spatial sub-division which maps to the main areas of focus of transport models.

This theoretical framework underlying paper is based on Truong and Hensher (2012) which demonstrates a formal theoretical link between a series of discrete choice logit models, as used in disaggregated transportation and location models, and aggregate computable general equilibrium models, to ensure theoretical and empirical consistency between the inputs and outputs associated with both modelling capabilities.

2.1 TRESIS-SGEM

When there are improvements in some parts of a transport network, first there will be some short run behavioural responses in the form of changes in mode and time of day of travel. In the medium to longer term, changes in the transport network also implies changes in accessibility (in relative and absolute terms) to housing and employment opportunities in different parts of an urban area. This will then lead to other medium term behavioural responses in the form of changes in employment and residential locations; changes in dwelling type choice – stand alone house, town house, apartment, and tenures – rent vs. own; changes in working hours, in the number and composition of cars owned and in their usage, etc. To capture the extent of these behavioural changes accurately, often, we need a suite of disaggregate behavioural models to follow each of the above types of changes in an accurate and consistent manner. Such a suite of models has been constructed for the Sydney Metropolitan area (SMA) in the 'transport environmental strategy impact simulator' (TRESIS) developed at the Institute of Transport and Logistics Studies (ITLS) (Hensher (2002); Hensher and Ton (2002)).

Next, to ensure these disaggregate behavioural responses interact consistently with the supply and demand conditions in the rest of the local and regional economy, we need a computable general equilibrium model framework to embed these disaggregate behavioural responses within the structure of the local economy, and to allow for forward and backward linkages between transport, land-use sectors, and the rest of the economy, as well as between different locations of the geographical area under study. Such a model has also been constructed for the SMA, called Sydney General Economic Model (SGEM) and linked to the TRESIS model in the form of an integrated transport-land use-economic model (Truong and Hensher (2012)). This integrated transport - land use – economy model (TRESIS-SGEM) is then used in this study for the analysis of the WEIs of a specific transport improvement project in Sydney called the North West Rail Link (NWRL) project.

2.1.1 An overview of TRESIS

The TRansport and Environmental Strategic Impact Simulator (TRESIS) is a microsimulation package. It is designed as a policy advisory tool to evaluate, at a strategic level, the impact of transport and non-transport policy instruments on urban passenger travel behavior and the environment, with a wide range of performance indicators. As an integrated model, TRESIS offers users the ability to analyse and evaluate a variety of land use, transport, and environmental policy strategies or scenarios for urban areas. The behavioral engine of TRESIS encompasses key household, individual, and vehicle-related decisions; in particular where a household chooses to locate (and the type of dwelling to live in), where the workers from that household will work, the household's number and type of vehicles and level of use by trip purpose, and the means of travel that will be used for household member trips by departure time. Also, within the package, the total levels of trip making and an origin-destination (O-D) matrix are estimated for each trip purpose, and the resulting trips are assigned to a strategic network.

TRESIS replicates the behaviour of the different decision makers such as households and travel makers. The model allows testing of various scenarios associated with land use, transport, environmental policies, and projects giving output in summary tables for each of 14 zones for the Sydney metropolitan area (including the Central Coast), as shown by Figure 1 1[4], cross-

[4] TRESIS can accommodate more than 14 zones but the run times increase substantially as we allow for more zones.

tabulated by household types, household incomes and residential zones, and in more detailed format by origin and destination (OD), by different times of day and by different simulation years.

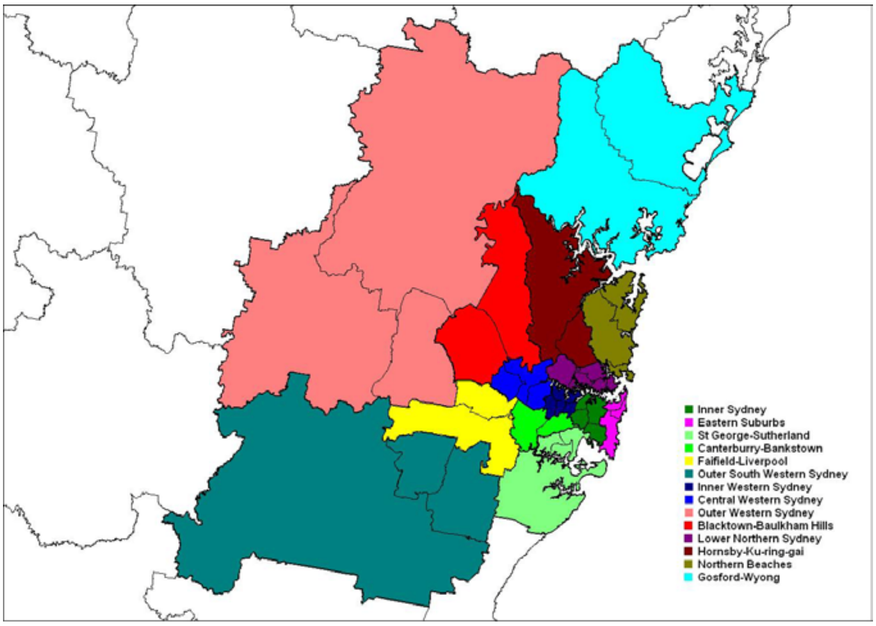

Figure 1: The 14 TRESIS zones

2.1.2 An overview of SGEM

In building a framework in which to use the outputs of TRESIS, together with specific economy wide impact equations, the spatial entity has been defined to match the zonal system used by TRESIS. Each zone is a 'mini' economy in the SGEM, with 'trade' occurring between the economies in the form of employment and income flows between different zones based on the economic characteristics of the economies of each zone, as well as the transport and land use links between the zones.

Within SGEM, an improvement in the transport links will affect the economic flows, which in turn will change the distribution of housing and employment opportunities among the zones. Redistribution and/or growth of economic activities, and the flow of these activities between the zones, can result in agglomeration effects for certain zones, but opposite effects for other zones. The net effect can only be estimated accurately if we allow for the 'rebalancing' or equilibrating effects which are specified in SGEM. These are captured by the aggregate economic variables such as employment, income, and outputs of different sectors of the spatial economies, and also within the transport and land use models described in terms of the equilibrating choices among the alternative modes, routes, housing and work locations.

With a fully-fledged SGEM model, each separate spatial zone will be characterised by an industry structure which can specify the types of industry outputs produced and inputs used (including capital, labour, land, natural resources as well as intermediate inputs), and the sources of these inputs, as well as the destinations of the outputs. In addition, each separate spatial zone will be characterised by a household or private consumption structure such that the pattern of expenditure on various types of commodities (including transport and housing as two major commodities in the bottom up transport land use model) will also be characterised. But such a fully-fledged SGEM is data demanding. Therefore, in a simpler version of SGEM, industry structures of different zones are simply assumed to be the same as that of the whole area with only outputs scaled so as to match with empirical data.

2.1.3 Linking TRESIS to SGEM

The linking of TRESIS to SGEM is to ensure that changes in the behavioural variables (choice decisions) in TRESIS are consistent with changes in the aggregate economic variables of the wider economy in SGEM, and to 'endogenise' those variables in TRESIS which are often assumed to be 'exogenous when it is run in a 'stand alone' mode.. Thus, for example, following changes in the choices between different work and residential locations in TRESIS, the employment figures as well as wage levels of the labour forces of different occupations in various industries in different zones need to be 'endogenised', not only according to the demand and supply conditions for labour in these different industries and occupations across the different zones in SGEM, but also consistently with the choice results in TRESIS. Furthermore, due to potential agglomeration (and dis-agglomeration) effects, changes in wage levels and output levels of different industries in SGEM need to take into account changes in labour productivity which can come about as a result of changes in 'effective densities' of employment estimated for different zones following from changes in locational choice behaviours in TRESIS as a result of a transport improvement.. Similarly for the housing sector: residential location choices affect the demand for housing in various locations, which must be matched with supply functions for housing in these zones using the equilibrating factor, housing rent. In turn, rent (as in the Venables (2007) model) can be considered as a 'residual'[5] variable after allowing for changes in wages due to productivity improvement, and changes in transport costs.

3. The agglomeration effect

According to Maré and Graham (2009, p. 2): "Agglomeration economies are positive externalities derived from the spatial concentration of economic activity…Since transport investments can increase the scale and efficiency of spatial economic interactions by lowering travel times and improving connectivity, we might expect positive external effects via agglomeration economies". To measure the benefits of agglomeration economies, first, an 'intermediate' concept of 'effective density'[6] is used (Graham, 2007), then the relationship between the change in this effective density and (labour) productivity is empirically measured giving rise to the concept of 'agglomeration elasticity' defined as an elasticity measure of the (percentage) change in (labour) productivity as a result of a (percentage) change in effective density (of employment). Agglomeration elasticity therefore measures the extent of the benefits/costs of (employment) agglomeration/dis-aggolmeration, while effective density is a measure of the extent of (employment) agglomeration itself.

Although the concepts of agglomeration economies and benefits/costs are simple to define, it is more difficult to explain theoretically as well as measure empirically these concepts. First, there is the issue of 'causality' between agglomeration and productivity: whether agglomeration causes productivity to improve, or in fact it just follows from the latter[7] (e.g. do firms with higher productivity simply want to follow each other and locate in similar places). Next, even if assuming that agglomeration causes productivity improvement, the question is what are the mechanisms causing this to happen? Traditionally, following the three examples given by

[5] Although rent is considered as a 'residual' in an experiment where productivity increases and changes in transport costs are determined primarily by the exogenous shocks to the system (i.e. transport project), it can play a different role in a different experiment where, for example, subsidies or taxes on rental income can play the role of a policy variable with consequent impacts not only housing decisions, but also on work location choices because these decisions are inter-connected (in TRESIS sub-model). This means in a general equilibrium context, taxes and subsidies (on rental income) can influence not only work location choices but also (if this leads to changes in employment densities) on agglomeration effect itself.

[6] Which is constructed for employment number rather than for firm number, implying we are interested only in the agglomeration of workers, and not of firms.

[7] The issue is similar to the question: whether transport infrastructure investment leads to economic development, or in fact economic development calls for or attracts further transport infrastructure investment (see, for example, Eberts and McMillen (1999)).

Marshall (1890), the explanations are that: close proximity between intermediate goods suppliers and their final goods producers allows for cost savings; a larger pool of labour allows for a finer division of labour and providing incentives for workers to invest in skills; firms and workers learn from each other when in close proximity, i.e. a form of knowledge spillovers or scale economies external to the firm and industry, but internal to a particular urban area (see Graham, 2007b;, Graham *et al.*, 2010). More modern explanations (Duranton and Puga, 2004) include the concepts of 'sharing' and 'matching' as well as 'learning': sharing of indivisible facilities, intermediate suppliers, workers and consumers by firms facilitating a reduction in fixed costs,. In addition, the matching of skill requirements by firms and availability by workers is made easier if there is close between larger pools of firms and workers (Duranton and Puga (2004))

To test for the hypothesis of causation requires extensive time series data, which are not readily available for a small geographical area like the SMA. Furthermore robust and unbiased estimation of the parameters for the agglomeration-productivity relationship requires data which may not be available.[8] Given the fact that the scope of our study is not only to try to estimate the agglomeration elasticities for the SMA, but also to establish a comprehensive model framework for the application of this elasticity into the measurement of WEIs for a transport project such as the NWRL project (see below), we therefore pursue the empirical estimation with only a limited objective in mind: how to obtain some 'preliminary' estimates of the agglomeration elasticities, based on the spatial data that are available to us, comparing these with other estimates to ensure that they fall within the range of other estimates and then to apply these estimates to the model to illustrate the usefulness of the approach.[9] Future improvements of the model can then concentrate on more accurate estimates of the elasticities, given better access to more extensive spatial data bases.

3.1 The measurement of effective employment density

The data used for this study are sourced from the 2006 Australian Bureau of Statistics (ABS) *Journey to Work* and the New South Wales Bureau of Transport Statistics *Household Travel Survey* data. The database consists of approximately half million records of the journey to work of approximately 1.5 million workers in the SMA with details of their occupations in different (single-digit) industry classifications, together with information on gross personal income and hours worked per week. Based on these data, we estimate the employment level and the average level of wage rate for different categories of occupations and industries across the 14 TRESIS zones of the SMA. The employment *effective density* measure for each zone, and for each industry category, is then calculated using the following formula[10] (Graham, 2007; Maré and Graham, 2009; Melo, Graham and Noland, 2009):

$$U_{iz} = \frac{E_{iz}}{\left(\sqrt{A_z / \pi}\right)^{\alpha}} + \sum_{s}^{s \neq z} \left[\frac{E_{is}}{(d_{zs})^{\alpha}} \right]; \quad i = 1,...,I; \quad z, s = 1,...,Z.. \tag{1}$$

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[8] For example, data on capital, land, and other material inputs into production activities at the traffic or TRESIS zonal level are not available in Australia; therefore the estimation of (total factor or output) productivity based on the concept of a production function is not feasible for the SMA, so we have to rely instead on the measurement of labour productivity only, with the necessary assumption that wages can be used as a proxy for this productivity (assuming a perfectly competitive market for labour and product output)

[9] The validity of our approach, therefore, does not depend critically on the empirical issues surrounding the estimation of these elasticities, although we make every attempt at ensuring that these estimates are sufficiently accurate to enable them to be used in the model with confidence. The advantage of using our own (location-specific) estimates rather than using results from other studies is that agglomeration elasticities are well known to depend critically on each specific geographical context. Encouragingly, as can be seen from the results reported below, our estimates are very close and fall within the range of the results of other studies and also conforming to the pattern of variation (across industries) that are found in other studies (see Tables 1 and 2)

[10] The Effective Employment Density in each of the 14 TRESIS zones by Occupation categories is available on request.

where Eiz is a measure of employment in industry i in zone z, and dzs is the distance between zone z and zone s. Az is the land area of zone z, so that $\sqrt{A_i / \pi}$ is an estimate of the average distance between jobs within zone z. In principle, the distance decay parameter should be empirically estimated, but given the limited availability of firm-specific spatial data in Australia, and in conformity with other studies (see Graham, 2007; Maré and Graham, 2009), it is assumed α=1.[11]

3.2 *The estimation of agglomeration elasticities*

The next step, as identified above, is to use the measurement of effective employment density to measure the agglomeration elasticities; this is undertaken within the SGEM. The agglomeration elasticity measures the (percentage) change in output productivity as a result of a (percentage) change in employment effective density. To measure output productivity directly would involve the estimation of an aggregate production function with multi-factor inputs (labour, capital, land) as well as material and other intermediate commodities as inputs. Lack of data on these factors and material inputs *at a zonal level* for different industries in Australia means that an aggregate production function cannot be estimated to allow changes in *multi-factor productivity* for each zone and for each industry to be identified. The approach of this paper is to focus on a narrower concept of factor productivity, namely *labour* productivity, based on an assumed relationship between labour productivity and its ultimate outcome, namely, the average wage rate for labour in different industries and in different zones.[12]

Two statistical relationships are examined to estimate agglomeration elasticities. The first specification takes the form in equation (2).

$$\ln(W_{izo}) = \beta_i + \gamma_i \ln(U_{izo}) \quad z = 1,...,Z; \quad o = 1,...,O.. \tag{2}$$

$\ln(W_{izo})$ is the logarithmic (or percentage) change in the wage level for occupation o associated with industry i in zone z, and $\ln(U_{izo})$ is the logarithmic (or percentage) change in accessibility to employment for occupation o in industry i from this zone. β_i is an industry specific constant term, and γ_i is the measure of agglomeration elasticity for industry i (estimated using the observations from all zones z's and for all occupations o's).[13] A second specification (equation (3)) pools data from all industries to estimate a relationship between $\ln(W_{izo})$ and $\ln(U_{izo})$.

$$\ln(W_{izo}) = \beta + \gamma_i \ln(U_{izo}) \quad z = 1,...,Z; \quad o = 1,...,O; \quad i = 1,...,I.. \tag{3}$$

β is now a constant term which is constrained to be the same for all industries and ε_i is an industry-specific agglomeration elasticity. If γ is further constrained to be the same for all industries, then the estimated value of γ will give an 'average' value for the agglomeration elasticity for all industries.

[11] In a recent study by Graham *et al.* (2010), it was found that the distance decay parameter α is slightly larger than 1 (1.122) for manufacturing but much larger (1.746 – 1.818) for business and consumer services sectors. This implies that the effects of agglomeration diminish more rapidly with distance from source for service industries than for manufacturing. But then to counter-balance this, the estimated values of the agglomeration elasticities are much larger for service industries (0.08 for business services) than for manufacturing (0.024). It is also likely that because of the assumption of a unitary distance decay parameter (α=1) in our study (as it is in other studies), the agglomeration elasticities estimates will tend to be a little higher than had we allowed for a non-constant and non-unitary distance decay parameter.

[12] If we assume labour is paid its marginal productivity, then any increase in labour productivity will flow on to its wage rate. If the flow on is not 100 percent and provided there is a steady relationship between improvement in labour productivity and change in the wage rate (perhaps through strong union bargaining), then the percentage change in the wage rate will be correlated with the percentage change in labour productivity.

[13] γ_i. thus measures the compounded effects of changes in agglomeration on changes in labour productivity and the passing through of this improvement in labour productivity to wage rate.

When equation (2) is applied to each industry data set separately, γ_i is assumed to be industry-specific as is the constant term β_i. This implies that, in addition to the agglomeration effects (γ_i), there may be other shocks to labour productivity occurring in the rest of the economy which are industry-specific, and captured by the constant term β_i in equation (2). When equation (3) is estimated using pooled industry data, it assumes there are *no* other shocks to labour productivity in the rest of the economy apart from the agglomeration shocks. The constant term β here is constrained to be the same for all industries, while the agglomeration elasticities (γ_i) can be industry-specific. An alternative estimation gives a value for γ when it is constrained to be the same for all industries to provide an average across all industries. Table 1 gives a comparison of the results from estimating equations (2) and (3) and shows that the estimated values of γ will generally be lower when β is assumed to be constant across industries and estimation is using pooled industry data. To remain conservative with respect to the estimated value of agglomeration elasticities, we use the results of estimating equation (3) in the case study of the next section. [14]

Table 1: The estimation of agglomeration elasticities in this study

	Agglomeration Elasticity estimated using industry-specific data			**Agglomeration Elasticity using industry-pooled data**	
Industry Class	**(γ_i)**	**t-stat**	**R^2**	**(γ_i)**	**t-stat**
Agriculture, Forestry & Fishing	.252***	3.15	.13	.047***	3.13
Mining	.406***	3.53	.11	.163***	5.32
Manufacture	.031*	1.74	.03	.035***	6.40
Elec., Gas, Water &Waste Services	.205***	2.72	.16	.108***	13.09
Construction	.020	1.14	.02	.051***	9.04
Wholesale Trade	.112**	2.23	.19	.034***	5.74
Retail Trade	.022	1.52	.02	.003	.65
Accommodation & Food services	-.049**	-2.59	.06	-.011*	-1.95
Transport, Postal & Warehousing	.029	1.58	.02	.044***	7.57
Information Media & Telecom.	.095**	2.12	.14	.051***	8.43
Financial & Insurance Services	.162	4.66	.27	.058***	9.62
Rental, Hiring & Real Estate Services	.085***	5.16	.22	.057***	7.86
Professional, Scientific & Tech. Services	.073***	5.84	.29	.055***	10.17
Administrative & Support Services	.070***	4.52	.14	.030***	4.85
Public Administration & Safety	.056***	4.21	.14	.062***	11.23
Education & Training	.077***	8.55	.33	.047***	7.79
Health Care & Social Assistance	.075***	5.99	.19	.029***	4.76
Arts & Recreation Services	.102***	5.29	.29	.032***	4.48
Other Services	.037***	2.66	.04	.007	1.04
Average				.021***	4.94
			No. of Obs. For each regression: 112	**R^2 = .232 No. of observations for pooled data: 2079.**	

***, **, * Significant at 1%, 5%, 10% level.

[14] To test for the accuracy of the linear log-log relationship assumed in equation (3), we also estimate a quadratic form given by:

$$\ln(W_{izo}) = \beta' + \delta_i \ln(U_{izo}) + \theta_i [\ln(U_{izo})]^2 \quad z = 1,...,Z; \quad o = 1,...,O; \quad i = 1,...,I..$$

Although the adjusted-R^2 improves somewhat (from .0.232 to 0.275) as can be expected, the *t*-statistics for both (δ_i) and (θ_i) are insignificant for industries (1-5, 8-9, 15). The estimated (θ_i) parameters, however, are all positive (except for industries 2 and 8). This implies that the actual agglomeration elasticities would tend to be *higher* than the estimated value of (γ_i) in equation (3) if variations in effective employment densities are *larger* than those assumed in our studies. Therefore, to test for the sensitivity of our model results, we have also run the experiment with the assumed values of agglomeration elasticities being equal to *twice* the values of the estimated (γ_i). See the next section.

Table 2 compares the results shown in Table 1 with those of other studies. Compared to the results of Rawnsley and Szafraneic (2009) which are estimated for the city of Melbourne, the estimated (labour) agglomeration elasticities are generally lower, but compared to the results of Mare and Graham (2009) and Melo et al (2009) for New Zealand and the UK, the results are more comparable. It is worth noting that both this study and the Rawnsley and Szafraneic study show agglomeration elasticities that are statistically significant for the following industries: Financial & Insurance Services, Education and Training, Health Care & Social Assistance, while statistically insignificant for Accommodation and Food services, and Manufacture. However, there are differences: in contrast to Rawnsley and Szafraneic results, which show insignificant agglomeration effects for Wholesale trade, but significant results for Retail trade, our study shows the opposite results, namely statistically significant agglomeration effects for Wholesale trade but not for Retail trade.[15] In general, however, our estimated agglomeration elasticities are within the range of those estimated from other studies and also show some similar variation across manufacturing and services industries as found in other studies.

Table 2: Comparison of estimated agglomeration elasticities of (output and labour) productivity with respect to effective employment density in different studies

Industry Class	This study (see Table 1) (labour agglomeration elasticity only)			Rawnsley & Szafraneic (2009) labour agglomeration elasticity only		Graham et al (2010)	Mare and Graham (2009) (Table 7 for NZ)		Mare and Graham (2009) (Table 4 for the UK)
	industry-specific data		industry-pooled data			Output Agglo_ meration Elasticity	Labour Agglo_ meration Elasticity	Output Agglo_ meration Elasticity	Output Agglo_ meration Elasticity
	(γ_i)	R^2	(γ_i)	(γ_i)	R^2				
Agri., Forest. & Fishing	.252	.13	.047***				.008	-.107	
Mining	.406	.11	.163***				-.180	.022	
Manufacturing	.031	.03	.035***	-.04	.05	.024	.042	-.012	.024
Elec., Gas, Water & Waste	.205	.16	.108***						
Construction	.020	.02	.051***	.11	.60	.034	.012	.038	.088
Wholesale Trade	.112	.19	.034***	.01	.00		.033	.066	
Retail Trade	.022	.02	.003	.08	.38	.024(a)	.046	.037	
Accom. & Food services	-.049	.06	-.011*	.09	.08		.066	-.015	.044
Trans., Post. & Warehouse	.029	.02	.044***	-.09	.19		.017	.032	.049
Info., Media & Telecoms.	.095	.14	.051***				.023	-.026	.082
Financial & Insur. Servs	.162	.27	.058***	.13	.29		-.014	-.028	.180
Rent., Hiring & Real Est.	.085	.22	.057***	.18	.59	.083(b)	.025	.054	.084
Prof., Sci., & Tech. Services	.073	.29	.055***						
Admin. & Support Services	.070	.14	.030***						.292(c)
Public Admin. & Safety	.056	.14	.062***	.01	.00				
Education and Training	.077	.33	.047***	.05	.32		.082	.065	
Health Care & Social Asstn	.075	.19	.029***	.10	.61		.003	.022	
Arts and Recreation Services	.102	.29	.032***	.29	.43		.004	-.014	
Other Services	.037	.04	.007	.07	.03				
Average			**.021*** **				**.034**	**.012**	

***, **, * Significant at 1%, 5%, 10% level.
(a) Consumer services, (b) Business services, (c) Public services.

The next section applies these agglomeration elasticities obtained from the pooled data model (equation 3) in the context of a case-study of the proposed North-West Rail Link project in Sydney, to identify the mark-up on traditional user benefits associated with the wider economy impacts.

[15] These differences may reflect the fact that different cities may have different geographical and economic structures which tend to encourage different types of agglomerations and with respect to different economic activities.

4. The north-west Sydney rail project: A case study

The NSW Government announced in early 2011 its plan to construct an extension of the CityRail network into the Hills District of Sydney. Known as the North-West Rail Line (NWRL), the NWRL is a 23-kilometre rail line between Epping and Rouse Hill. The project includes construction of six new stations at Cherrybrook (Franklin Road), Castle Hill, The Hills Centre, Norwest Business Park, Kellyville (Burns Road) and Rouse Hill (See Figure 2). The NWRL Project will include approximately 3,000 park and ride spaces as well as bus interchange facilities, and will provide rail access for the first time from the growing North West region to major employment centres in Norwest Business Park, Macquarie Park, St Leonards, Chatswood, North Sydney and the CBD. It is suggested that by providing rail access through to Rouse Hill, the new line will also support future residential and commercial development in the North West growth centre. The rail link will serve a population of 360,000, which is expected to grow to 485,000 by 2021, and by 2036, the new rail link is expected to service a region with more than 145,000 jobs.

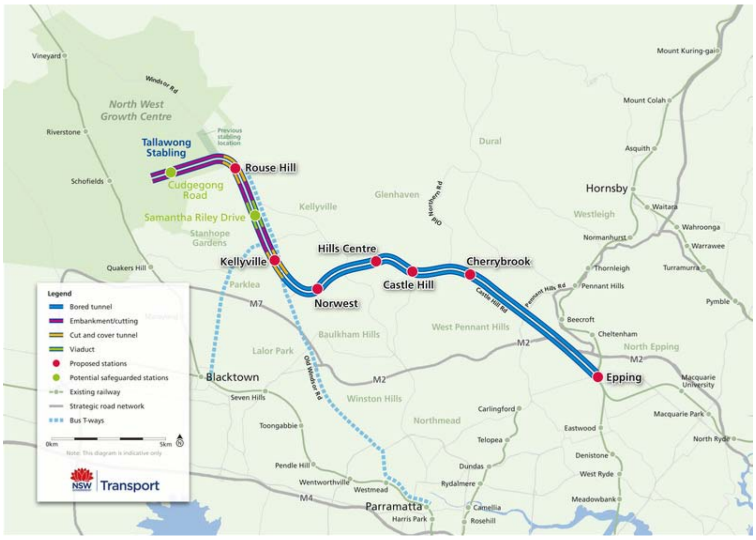

Figure 2: Proposed NWRL

4.1 The treatment of the NWRL project in TRESIS

In the context of the TRESIS model, the NWRL Project is assumed to affect access and egress times to/from railway stations in the Blacktown-Baulkham Hills zone, and in-vehicle time for train travel between Blacktown-Baulkham Hills zone and the Inner Sydney zone (see Figure 2).

The NWRL Project is assumed to reduce *average* access and egress times to railway stations to 10 minutes from the current 19 minutes. In-vehicle time is assumed to change in order to reduce total travel time (including access time, egress time and in-vehicle time) between Blacktown-Baulkham Hills and Inner Sydney to 95 percent of the original travel time. The fixed reduction in average access and egress times means that the average in-vehicle time between the Blacktown-Baulkham Hills and Inner Sydney zones increases by 3.6% overall (or by 3.16 minutes) and total travel time decreases by 5.84 minutes overall. Travel time to and from Blacktown-Baulkham Hills to zones other than Inner Sydney is also assumed to decrease by a total 5.84 minutes, if travel by train to these zones passes through Inner Sydney.

As a result of these changes in average access, egress, and in-vehicle travel times (by train) between Blacktown-Baulkham Hills and other zones in the Sydney Metropolitan Area (SMA) following the NWRL Project, the probability of choosing train as the main mode of travel between different zones will change. TRESIS identifies more people who are predicted to choose to use the train as the main mode of travel *to* Blacktown-Baulkham Hills, irrespective of the origin of travel, not just from Inner Sydney. More people *from* Blacktown-Baulkham Hills will also choose to use train as the main mode of travel from this zone to other zones (except within Blacktown-Baulkham Hills). Similarly, more people *from* Inner Sydney will also choose to use train as the main mode of travel from this zone to *all* other zones, including Blacktown-Baulkham Hills. However, apart from the zones of Inner Sydney and Blacktown-Baulkham Hills, *relatively* less people will choose train to travel to zones other than Blacktown-Baulkham Hills since more people are using train to travel to Blacktown-Baulkham Hills as a result of the NWRL Project. Overall, the increase in train patronage is at the expense of other modes (including bus).

The changes in the mode of travel also affect the decision on work place location choice. This is modelled in TRESIS and the results identify that *more* people will choose to work in Central West Sydney in zone 8 (which includes Parramatta) and in Canterbury-Bankstown (zone 4) as a result of the NWRL Project, but at the same time *less* people will choose to work in Fairfield-Liverpool (zone 5), Inner West Sydney (zone 7), and in the Blacktown-Baulkham Hills (zone 10) itself. The last result is interesting because improvements in accessibility provided by the new rail link between Inner Sydney and Blacktown-Baulkham Hills means *less* people will choose to go to work in Blacktown-Baulkham Hills, including the people living in Blacktown-Baulkham Hills itself. This is because the NWRL Project improves the public transport *network* through the introduction of a new rail *link* and, as a result of this greater metropolitan accessibility people have more choices of places to work than before. The result is a redistribution of employment locations, which favours other zones outside the zone in which the new link resides. This has important implications. For example, projects which may currently be viewed as ‘alternative’ transport investment projects may in fact be supplements or *complements* rather than competing *substitutes* if overall and total *network* effects are taken into consideration, as opposed to separately and myopically considering only the individual *links* effects.

As a consequence of these *network* effects, *employment* in different zones will also change. Table 3 shows that Canterbury-Bankstown (zone 4) and Central West including Parramatta (zone 8) gain in terms of employment, but Fairfield-Liverpool (zone 5), Inner West Sydney (zone 7) and Blacktown-Baulkham Hills (zone 10) will lose. Nevertheless, despite the loss in (absolute) number of employments for these zones (zone 5, zone 7, zone 10), improved *accessibility* to employment opportunities in other zones *from* these zones means that the level of employment *density* for these zones do not need to decrease. This is shown in Table 3.

Table 3: Changes in the total number of employments in different zones as a consequence of the NWRL project

Zone no.	Work Place	Before Project	After Project	Absolute change	% change
1	Inner Sydney	387740	387744	4	0.001
2	Eastern Suburbs	62106	62106	0	0
3	St.George and Sutherland	86702	86681	-21	-0.024
4	Canterbury and Bankstown	72075	72529	454	0.629
5	Fairfield Liverpool	83642	83000	-642	-0.768
6	Outer South West Sydney.	52089	52146	57	0.11
7	Inner West Sydney.	56965	55631	-1334	-2.342
8	Central West Sydney.	143849	146213	2364	1.643
9	Outer West Sydney.	80119	80159	40	0.051
10	Blacktown and Baulkham Hills	116909	115926	-983	-0.841
11	Lower North Shore	175129	175130	1	0
12	Hornsby and Kuringai	61777	61846	69	0.112
13	Northern Beaches	65415	65424	9	0.013
14	Gosford and Wyong	73833	73824	-9	-0.013
	Total	**1,518,350**	**1,518,358**	**8**	**0.001**

Table 4 shows the level of employment density for the 'losing' zones have *increased*, and even more so than other zones despite the (assumption) that the *total* amount of employment in all 14 zones of the SMA is to remain unchanged (as shown in Table 3). Thus the NWRL Project brings about an improvement in the transport *network*, and the employment *redistribution* effects arising from this network improvement means that total employment *density* for the SMA as whole has *increased* by about 0.013 % (Table 4, last row). Even though this may seem small, the benefits (e.g., agglomeration effects) arising from such a redistribution can still be significant, as the analysis in the next sections show.[16]

Table 4: Changes in employment density (i.e., accessibility to all employment opportunities) from various zones as a consequence of the NWRL project (aggregated over all industries)

Zone no.	Work Place	Before Project	After Project	Absolute change	% change
1	Inner Sydney	92871	92847	-25	-0.026
2	Eastern Suburbs	90532	90528	-4	-0.004
3	St.George and Sutherland	42927	42935	8	0.019
4	Canterbury and Bankstown	71394	71423	28	0.04
5	Fairfield Liverpool	42223	42255	32	0.075
6	Outer South West Sydney.	20472	20474	1	0.007
7	Inner West Sydney.	98207	98236	29	0.03
8	Central West Sydney.	68621	68643	22	0.032
9	Outer West Sydney.	21829	21826	-3	-0.013
10	Blacktown and Baulkham Hills	38566	38592	26	0.067
11	Lower North Shore	77323	77314	-9	-0.011
12	Hornsby and Kuringai	35502	35509	6	0.018
13	Northern Beaches	43306	43312	6	0.013
14	Gosford and Wyong	18783	18786	2	0.013
	Total	**762,557**	**762,679**	**122**	**0.016**

[16] The small increase in total employment *density* (seen in Table 4) should be interpreted against the background of an assumption of no growth in total employment within the SMA as defined in our experiment and reflected in the results of Table 3 (note that the very small increase in total employment in Table 3 is due to statistical and numerical rounding errors only). This implies that despite no growth in total employment, a *redistribution* of these employment opportunities among the various zones can still result in a net positive increase in *accessibility* to these employment opportunities for workers living in this area. Accessibility in this case is defined in terms of the effective employment density measure, which in turn is defined in terms of physical employment opportunities weighted by physical distances (rather than by travel times).

4.2 Benefits of the NWRL project

4.2.1 Conventional' benefit measurement of the NWRL project using the TRESIS model

The introduction of the NWRL Project has a number of system wide impacts on the performance of the entire passenger transport network, linked to the many behavioural responses that travellers and households make as a consequence of increased accessibility into and out of each TRESIS zone in the SMA. TRESIS recognises and accounts for responses associated with choice of mode, time of departure, workplace location, residential location (including dwelling and tenure type choice), and even changes in the number and composition of vehicles in each household (as explained in more detail in a previous section), all subject to equilibration in the travel, location and vehicle ownership markets. Allowance is also made for the time required for the adjustment of each response, ranging from an immediate adjustment to a longer period adjustment.

The most important evidence relates to the overall change in the traditional set of transport related user benefits, as quantified by generalised cost, as well as the total expected maximum utility (or benefit surplus). The change in total aggregate user benefits measured by the change in expected maximum utility (converted to dollars) is identified as $25.486 m in $2006. This is equivalent to a change in generalised cost per person trip of approximately 0.3 cents on average (spread across all trips in the SMA) or 4 cents of total expected maximum utility (or consumer surplus) per person trip.

In the light of the redistributive changes that have been identified in the previous section, it is important to recognise that an improvement in rail services in a specific location changes the accessibility associated with inflows and outflows for every zone. Consequently the net impact of the NWRL Project becomes somewhat complex to work through. In particular, improved travel times (and increase in fares paid) associated with NWRL Project will actually increase in-vehicle main mode travel time by train while reducing the access (or egress time) to/from the train in the zone in which the NWRL resides. Depending on the amount of modal switching towards the train, there will be an improvement (albeit small) in the travel times on certain roads for both car and bus, which will, through traffic assignment and user equilibration, result in some small move back to car and bus until we establish some equilibration where there are no further gains in user benefit.

Improved accessibility can also result in some households relocating even further away from the CBD since now they can obtain possibly a better lifestyle further out without a reduction in accessibility. This in itself can lead to some amount of increase in travel times for some members of households even though the commuter (for example) who switches to train now may be no worse off in travel time. TRESIS allows for these interactions and responses in the choice of travel and location. What might appear counterintuitive in the context of the NWRL Project may indeed be very plausible given the many ways in which individuals and households respond. The benefit will be there, but may not be fully captured by the traditional treatment of generalised cost. The consumer surplus measure is linked to all choice responses and allows for unobserved influences not captured in observed measures of generalised cost (i.e., travel times and cost), and thus is a rich behavioural measure of all sources of user benefits from TRESIS

4.2.2 Measurement of the agglomeration effect and the wider economic benefit of the NWRL project using the SGEM model

The Wider Economic Impacts (WEIs) of the NWRL Project are quantified in our study primarily via the impact of the project on employment redistribution within the SMA (see Table 3). This is because for simplicity of assessment, we have assumed zero exogenous shocks to factors which can cause total employment opportunities within the SMA to grow, especially those factors which reside outside of the SMA [17]Therefore, the only major WEIs that can be quantified in our study are those associated with employment redistribution within the SMA resulting from an improvement in the transport system as delivered by the NWRL Project.

Employment redistribution can have two different effects. First, changing work location choices by workers represents relative shifts in labour supply functions between various locations. These relative labour supply shifts must be balanced against labour demand changes with the resulting changes in the equilibrium wage rate feeding back to the initial work location decision changes. In SGEM, however, labour demand is assumed to be perfectly elastic at the ongoing wage rate (which can be different for different zones and for different industries for any given occupation).[18]This assumption is partly due to a lack of empirical data, but also for reason of convenience because it implies wages in SGEM can only be changed if there are *shifts* in the demand (for labour) schedules, and these can only be the result of changes in *labour productivity* which in our study is assumed to be caused by agglomeration effects (to be considered next). Despite the fact that the wage level remains unchanged following the initial improvement in the transport system, *total income* for all workers in the SMA, however, can still change. This is because workers in changing their places of work are seeking for better jobs (with the improved accessibility to these jobs following a transport improvement). Therefore, rearrangement of work opportunities among workers living in different locations can still result in a net increase in total income for all workers, and this is a measure of the WEIs of the transport project. We refer to this component of the WEIs as the 'general equilibrium (GE) effects', to be distinguished from the 'agglomeration effects' proper which are to be associated with *changes* in labour productivity (and hence changes in wage level) caused by the agglomeration (or dis-agglomeration) of workers to specific locations following an improvement in the transport network. In short, the total WEIs of employment redistribution within the SMA will consist of two components: the general equilibrium effects – when agglomeration elasticities are assumed to be zero, and agglomeration effects when agglomeration elasticities are assumed to be non-zero. In trying to measure these two different components of the WEIs for the NWRL project in our study, thus, we carry out three different experiments. First, we run a simulation of the NWRL project in TRESIS-SGEM with the agglomeration elasticities set to zeros. This will give us only the GE effects. Next, we set agglomeration elasticities equal to the values estimated for this study and as described in section 3.2. This gives us the total WEIs from which we can derive the 'pure' agglomeration effects by subtracting the GE effects from this total effect. Finally, we can also carry out a sensitivity experiment by changing the values of agglomeration elasticities. In our study, we assume that they are *twice* the estimated values as used in experiment 2. This will give us the different (and expected to be larger) agglomeration effects when agglomeration elasticities are assumed to be larger.

Tables 5 and 6 report on the total WEIs (i.e., GE and agglomeration effects) of the NWRL Project assumed to be measured by the net increase (or decrease) intotal wage bill ($/week) for all workers employed following the implement of the Project. These WEIs can be measured either at *work locations* (Table 5) or at *residential locations* (Table 6). The results can show how certain zones can 'gain' in the sense of either increased volume of employment and/or improved labour productivity and wages following agglomeration or 'lose' because of the opposite effects. However, both Tables should give the same net *total* increase, which is 86,284

[17] Total employment in the SMA can grow only if there are changes to factors like population, migration, interregional and international trade, shifts in demand, technological change, etc. For a small project like the NWRL, the assumption that these factors remain unchanged is perhaps reasonable, but for a much larger infrastructure project, this assumption may need to be relaxed. To take account of these additional 'exogenous' factor changes will also require an extension of the SGEM model to take account of not just a local economic factors but also other regional and multi-national trade and economic conditions and linkages with the local economy which is beyond the scope of the present paper.

[18] This assumption is partly due to lack of data but also for reason of simplicity as explained in the text. To arrive at appropriate demand elasticities for

$/week for all zones in the SMA.[19] . From these Tables, it can be seen that, although *industries* located in zones 3, 5, 7, and 10 may lose out to other zones (because of employment redistribution away from these zones, see also Table 3), *workers* who live in these zones, however, can still gain (see Table 6) by having improved access to employment opportunities elsewhere rather than to those in their own zones.

The North-West Rail Link's planned route is designed to reduce travel times between the Blacktown-Baulkham Hills and Inner Sydney zones. The reduction in travel times improves the employment density of Blacktown-Baulkham Hills and the adjoining zone of Fairfield-Liverpool by making jobs more accessible to the population of surrounding population centres (such as Parramatta in Central Western Sydney). As would be expected, the greatest increases in employment density are seen in the zones along the new NWRL corridor as these areas become accessible (see Figure 3). However, Inner Sydney sees a small reduction in employment density in large part because the NWRL link makes it possible for more people to move further away. There is no or very small changes in the employment densities of zones far away from the NWRL because the changes in travel time to Blacktown-Baulkham Hills from these zones is only a small proportion of the total travel time.

Table 5: Changes in total income ($/week) at work place resulting from agglomeration effects as a consequence of the NWRL project.

Zone no.	Work Place	Before Project	After Project	Absolute change	% change
1	Inner Sydney	449620032	449619968	-64	0.000
2	Eastern Suburbs	57637300	57637256	-44	0.000
3	St.George and Sutherland	69749944	69733816	-16128	-0.023
4	Canterbury and Bankstown	58319344	58699056	379712	0.651
5	Fairfield Liverpool	67304880	66771244	-533636	-0.793
6	Outer South West Sydney.	39216376	39261300	44924	0.115
7	Inner West Sydney.	51985324	50727580	-1257744	-2.419
8	Central West Sydney.	134811936	137074576	2262640	1.678
9	Outer West Sydney.	61317452	61343636	26184	0.043
10	Blacktown and Baulkham Hills	100451352	99570008	-881344	-0.877
11	Lower North Shore	196333888	196333872	-16	0.000
12	Hornsby and Kuringai	53167624	53229664	62040	0.117
13	Northern Beaches	56837424	56845184	7760	0.014
14	Gosford and Wyong	53426096	53418096	-8000	-0.015
	Total	**1450178972**	**1450265256**	**86284**	**0.006**

[19] The small discrepancy between the totals in Tables 5 and 6 is due only to rounding errors.

Table 6: Changes in total income ($/week) at residential location resulting from agglomeration effects as a consequence of the NWRL project.

Zone no.	Work Place	Before Project	After Project	Absolute change	% change
1	Inner Sydney	146819536	146825328	5792	0.004
2	Eastern Suburbs	108089744	108090096	352	0.000
3	St.George and Sutherland	135377232	135383296	6064	0.004
4	Canterbury and Bankstown	70910704	70901192	-9512	-0.013
5	Fairfield Liverpool	78675624	78694328	18704	0.024
6	Outer South West Sydney.	70063552	70065440	1888	0.003
7	Inner West Sydney.	67294992	67332296	37304	0.055
8	Central West Sydney.	84708696	84688568	-20128	-0.024
9	Outer West Sydney.	100912920	100919176	6256	0.006
10	Blacktown and Baulkham Hills	149477248	149511808	34560	0.023
11	Lower North Shore	149079200	149082288	3088	0.002
12	Hornsby and Kuringai	115214528	115213920	-608	-0.001
13	Northern Beaches	99495952	99495896	-56	0.000
14	Gosford and Wyong	74059016	74061592	2576	0.003
	Total	1450178944	1450265224	86280	0.006

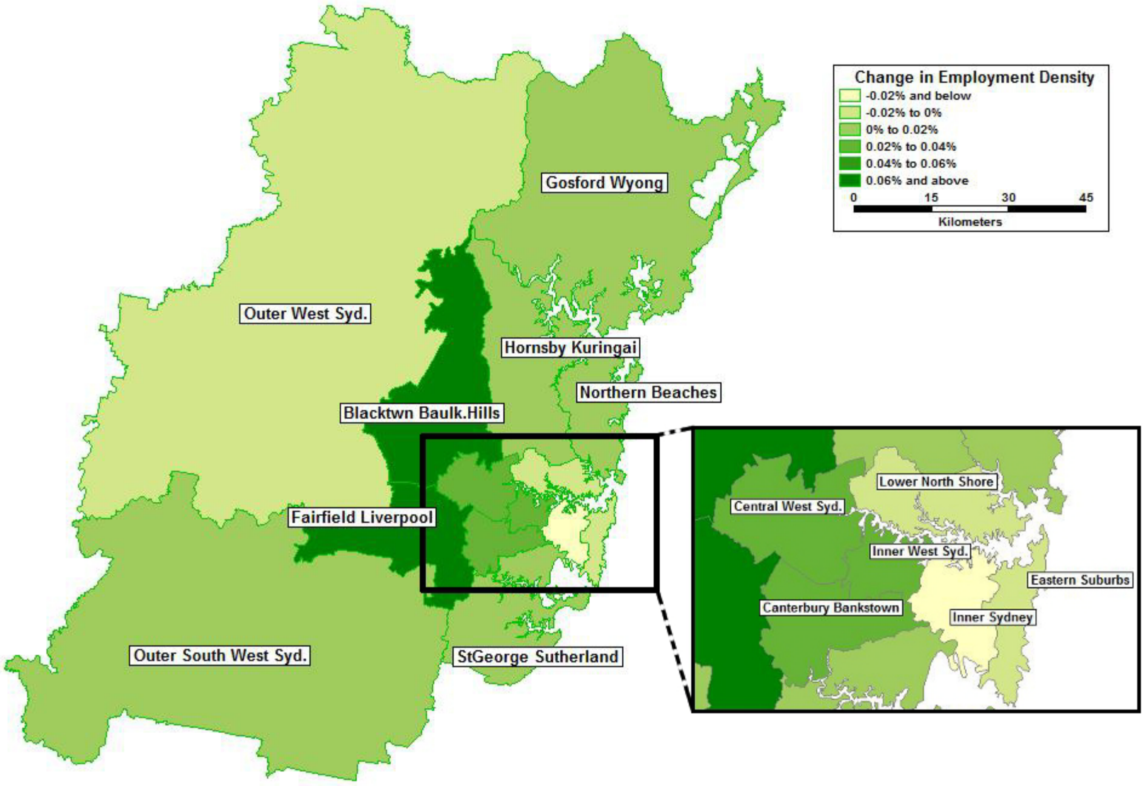

Figure 3: Changes in effective employment density

Table 7 shows the decomposition of the total WEIs into separate GE and agglomeration effects. From this Table, it can be seen that total agglomeration effect makes up only about 14.0% of the total WEIs (when agglomeration elasticities are assumed to be equal to the estimated values) but can increase to 19.4% if these elasticities are assumed to be equal to twice these estimated values. Even in this case, however, a (pure) agglomeration effect is still a smaller part of the total WEIs, the larger effects being due to general equilibrium impacts.

Table 7: Decomposition of the WEIs (changes in total income ($/week) at work locations) into general equilibrium and pure agglomeration effects for the NWRL project.

Zone no.	**Work Place**	**General equilibrium effects**	**Agglomeration effects**		**Total WEIs**		**% of agglomeration effects over total WEIs**	
			(*)	(**)	(*)	(**)	(*)	(**)
1	Inner Sydney	-64	0	0	-64	-64	0.0%	0.0%
2	Eastern Suburbs	-44	0	0	-44	-44	0.0%	0.0%
3	St.George and Sutherland	-16992	864	1544	-16128	-15448	-5.4%	-10.0%
4	Canterbury and Bankstown	377656	2056	4688	379712	382344	0.5%	1.2%
5	Fairfield Liverpool	-536148	2512	4060	-533636	-532088	-0.5%	-0.8%
6	Outer South West Sydney.	45088	-164	-1144	44924	43944	-0.4%	-2.6%
7	Inner West Sydney.	-1258756	1012	1972	-1257744	-1256784	-0.1%	-0.2%
8	Central West Sydney.	2261840	800	-976	2262640	2260864	0.0%	0.0%
9	Outer West Sydney.	26080	104	-1660	26184	24420	0.4%	-6.8%
10	Blacktown and Baulkham Hills	-884776	3432	8072	-881344	-876704	-0.4%	-0.9%
11	Lower North Shore	-16	0	0	-16	-16	0.0%	0.0%
12	Hornsby and Kuringai	61312	728	1376	62040	62688	1.2%	2.2%
13	Northern Beaches	7264	496	780	7760	8044	6.4%	9.7%
14	Gosford and Wyong	-8204	204	-804	-8000	-9008	-2.6%	8.9%
	Total	74240	12044	17908	86284	92148	14.0%	19.4%

(*) when agglomeration elasticities are assumed to be equal to estimated values as shown in column 5 of Table 1.

(**) when agglomeration elasticities are assumed to be equal to *twice* the estimated values.

Tables 8 and 9 show the breakdown of the changes in total income measured *at the work place*, by industry and occupation, and Tables 10 and 11 give similar breakdowns for changes in total income measured at each residential location.[20] From Table 8 it can be seen that industries in Fairfield-Liverpool (zone 5), Inner West Sydney (zone 7) and Blacktown-Baulkham Hills (zone 10) will lose out to the Central West Sydney (zone 8), and also to some extent Canterbury-Bankstown (zone 4) and Outer South West Sydney (zone 6). The industries which stand to gain the most are: Manufacturing, Wholesale Trade, Public Administration and Safety, Health care and Social Assistance, and also to some extent Finance and insurance, Transport, Post and Warehousing, Accommodation and Food, Construction, and Arts and Recreation. From the last column of Table 9, it can be seen that workers of all occupations will gain. However, a redistribution of employment will imply those working in zones 3, 5, 7, and 10 will tend to move to other zones, particularly zones 4, 6, 8, and 12.

[20] Note the small discrepancies between the sum totals in these Tables are due to rounding errors.

Table 8: Changes in total income ($/week) at work place as a measure of WEIs resulting from the NWRL project – by industry.

Industry	Work Location														
	Inner Sydney	East.Subs	St. Gge Suther	Canter Banks	Fairfd Livrp	Outer SW.Sydney	Inner W.Sydney	Central W.Sydney	Outer W.Sydney	Blacktwn Baulk. Hills	Lower N.Sydney	Hornsby Kuringai	Nth Beaches	Gosford Wyong	Total
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
Agr_For_Fish	-3	-2	93	426	-1446	547	-1391	2139	1368	-3074	-1	787	95	205	-259
Mining	-3	0	37	114	-437	364	-131	1498	520	-1755	-1	117	53	56	433
Manufacturng	2	2	-15141	77468	-146822	602	-134087	422014	-530	-171919	4	110	-2593	-2488	26624
ElyGasWatWst	-15	-8	2545	6245	-4888	1871	-17033	15554	3830	-13823	-9	871	921	573	-3365
Construction	-5	-4	261	24902	-31099	4672	-76698	134955	5641	-66339	-3	6549	1595	-84	4343
Wholes_Trade	2	2	-4820	29620	-47482	1272	-106469	230897	887	-92329	4	1640	-1808	-646	10770
Retail_Trade	-8	-8	2317	37722	-34901	6104	-110974	163697	8488	-88379	-5	10509	4822	108	-509
Accom_Food	-4	-2	536	12517	-11490	1358	-32269	48969	2194	-20656	-2	1878	1291	24	4344
TranPostWare	0	-1	-2663	28948	-34982	2158	-90210	147234	2585	-47698	1	1926	152	-1057	6394
InfoMediaTel	6	2	-675	5157	-4098	-185	-35140	48104	-1650	-7616	6	85	-612	-612	2773
FinanceInsur	0	-2	-1692	7187	-12759	-395	-88601	139563	-3431	-29186	2	310	-860	-23	10113
RentHirRealE	-11	-8	794	6999	-5772	1947	-34817	39120	1640	-12877	-6	2533	389	33	-35
ProfSciTech	-8	-5	3102	15013	-15622	1762	-116372	131598	1553	-56292	-4	14653	2965	1159	-16498
Admin_Supprt	-2	-2	-18	6421	-14075	1054	-20415	42136	473	-17486	0	1194	110	-472	-1081
PubAd_Safety	0	1	-6817	16115	-44465	1153	-78683	204672	-10155	-55119	2	-2417	-1813	-3402	19074
Edu_Training	-8	-6	2990	44386	-44678	10053	-106233	141063	15104	-80250	-4	16438	2649	597	2100
HlthC_SoAstn	-6	-6	3666	45142	-57907	8641	-159130	259593	-3625	-83521	-4	2449	411	-1204	14499
Arts_Recrtn	1	2	-1203	2370	-2806	-162	-9361	20546	104	-4624	2	100	-343	-414	4212
OthServcs	-5	-4	558	12964	-17912	2109	-39734	69293	1190	-28403	-2	2312	337	-352	2352
Total	**-67**	**-44**	**-16130**	**379713**	**-533636**	**44925**	**-1257745**	**2262644**	**26185**	**-881343**	**-20**	**62042**	**7761**	**-8000**	**86284**

Table 9: Changes in total income ($/week) at work place as a measure of WEIs resulting from the NWRL project – by occupations.

Occupation	Work Location														
	Inner Sydney	**East. Subs**	**St. Gge Suther**	**Canter Banks**	**Fairfd Livrp**	**Outer SW Sydney**	**Inner W Sydney**	**Central W Sydney**	**Outer W Sydney**	**Blacktwn Baulk. Hills**	**Lower N Sydney**	**Hornsby Kuringai**	**Nth Beaches**	**Gosford Wyong**	**Total**
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
Managers	-8	-5	-3819	72446	-89882	7038	-255490	448474	5209	-180010	0	13341	1721	-1507	0
Professionals	0	-2	374	95660	-120119	14365	-395695	615244	5347	-237588	0	24382	1421	-1415	1974
TechTrades	-10	-9	-3268	52288	-79716	5370	-133126	258786	5353	-103583	-6	7096	1794	-1074	9895
CommPersServ	-8	-6	37	20416	-29665	3399	-57428	117648	991	-43459	-1	3395	75	-1522	13873
ClericlAdmin	-8	-4	-3786	52009	-78590	4615	-218684	396734	-4755	-132718	-2	5132	330	-474	19798
SalesWorkers	-12	-7	-408	28465	-32367	3593	-82066	141018	5256	-57911	-3	5445	1621	-686	11939
MachOperDriv	-2	-3	-3725	32802	-66355	3040	-62007	172331	4339	-73415	2	656	255	-1239	6680
Labourers	-13	-10	-1536	25629	-36944	3507	-53248	112410	4447	-52661	-4	2596	544	-85	4631
Total	**-61**	**-46**	**-16131**	**379714**	**-533637**	**44926**	**-1257744**	**2262645**	**26186**	**-881344**	**-15**	**62042**	**7761**	**-8001**	**86297**

Table 10: Changes in total income ($/week) at residential location as a measure of WEIs resulting from the NWRL project – by industry.

Industry	Residential Location														
	Inner Sydney	East. Subs	St. Gge Suther	Canter Banks	Fairfd Livrp	Outer SW Sydney	Inner W Sydney	Central W Sydney	Outer W Sydney	Blacktwn Baulk. Hills	Lower N Sydney	Hornsby Kuringai	Nth Beaches	Gosford Wyong	Total
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
Agr_For_Fish	-3	-2	93	426	-1446	547	-1391	2139	1368	-3074	-1	787	95	205	-259
Mining	-3	0	37	114	-437	364	-131	1498	520	-1755	-1	117	53	56	433
Manufacturng	2	2	-15141	77468	-146822	602	-134087	422014	-530	-171919	4	110	-2593	-2488	26624
ElyGasWatWst	-15	-8	2545	6245	-4888	1871	-17033	15554	3830	-13823	-9	871	921	573	-3365
Construction	-5	-4	261	24902	-31099	4672	-76698	134955	5641	-66339	-3	6549	1595	-84	4343
Wholes_Trade	2	2	-4820	29620	-47482	1272	-106469	230897	887	-92329	4	1640	-1808	-646	10770
Retail_Trade	-8	-8	2317	37722	-34901	6104	-110974	163697	8488	-88379	-5	10509	4822	108	-509
Accom_Food	-4	-2	536	12517	-11490	1358	-32269	48969	2194	-20656	-2	1878	1291	24	4344
TranPostWare	0	-1	-2663	28948	-34982	2158	-90210	147234	2585	-47698	1	1926	152	-1057	6394
InfoMediaTel	6	2	-675	5157	-4098	-185	-35140	48104	-1650	-7616	6	85	-612	-612	2773
FinanceInsur	0	-2	-1692	7187	-12759	-395	-88601	139563	-3431	-29186	2	310	-860	-23	10113
RentHirRealE	-11	-8	794	6999	-5772	1947	-34817	39120	1640	-12877	-6	2533	389	33	-35
ProfSciTech	-8	-5	3102	15013	-15622	1762	-116372	131598	1553	-56292	-4	14653	2965	1159	-16498
Admin_Supprt	-2	-2	-18	6421	-14075	1054	-20415	42136	473	-17486	0	1194	110	-472	-1081
PubAd_Safety	0	1	-6817	16115	-44465	1153	-78683	204672	-10155	-55119	2	-2417	-1813	-3402	19074
Edu_Training	-8	-6	2990	44386	-44678	10053	-106233	141063	15104	-80250	-4	16438	2649	597	2100
HlthC_SoAstn	-6	-6	3666	45142	-57907	8641	-159130	259593	-3625	-83521	-4	2449	411	-1204	14499
Arts_Recrtn	1	2	-1203	2370	-2806	-162	-9361	20546	104	-4624	2	100	-343	-414	4212
OthServcs	-5	-4	558	12964	-17912	2109	-39734	69293	1190	-28403	-2	2312	337	-352	2352
Total	**-67**	**-44**	**-16130**	**379713**	**-533636**	**44925**	**-1257745**	**2262644**	**26185**	**-881343**	**-20**	**62042**	**7761**	**-8000**	**86284**

Table 11: Changes in total income ($/week) at residential location as a measure of WEIs resulting from the NWRL project – by occupations.

Occupation	Residential Location														
	Inner Sydney	**East. Subs**	**St. Gge Suther**	**Canter Banks**	**Fairfd Livrp**	**Outer SW Sydney**	**Inner W Sydney**	**Central W Sydney**	**Outer W Sydney**	**Blacktwn Baulk. Hills**	**Lower N Sydney**	**Hornsby Kuringai**	**Nth Beaches**	**Gosford Wyong**	**Total**
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
Managers	806	388	1612	-1075	3029	1233	8202	-4014	-52	6650	52	116	-162	723	0
Professionals	1188	-788	-384	-2290	1246	-893	11292	-5846	-524	2204	800	-2824	-300	-910	1971
TechTrades	539	-428	415	-2117	1961	426	3093	-2679	1499	6670	258	-836	-175	1269	9895
CommPersServ	929	378	906	-420	2048	541	1976	668	1186	4414	335	250	94	570	13873
ClericlAdmin	612	592	2126	-2010	4285	947	5762	-3862	3532	5498	-8	1582	484	259	19799
SalesWorkers	1063	156	-72	-1034	2538	-343	4728	-2696	-108	5357	1590	422	-74	413	11940
MachOperDriv	410	103	944	-378	2741	262	1439	-1134	472	1346	76	305	-76	172	6680
Labourers	241	-49	516	-191	860	-286	816	-562	253	2429	-5	378	150	81	4630
Total	**5787**	**353**	**6062**	**-9513**	**18707**	**1887**	**37308**	**-20125**	**6258**	**34568**	**3097**	**-608**	**-60**	**2576**	**86295**

These redistributive effects highlight the importance of distinguishing between a (transport) link-effect and network-effects where, as a result of improvement to a particular transport link, the whole transport network will change in its characteristics, leading to a rearrangement of employment and residential locations so as to capitalize on these changes. The resultant net effect may be some losses (i.e., negative redistribution) in employment opportunities in some areas, and gains (i.e., positive redistribution) elsewhere, but the system as a whole should gain because of improved accessibility and improved labour productivity as a result of the positive agglomeration effects. Workers therefore may choose to live in areas where employment opportunities may have declined, but still gain in personal income because of improved access to better jobs elsewhere.

4.2.3 The mark-up of WEI to conventional user benefits in the NWRL Project

In the short to medium term, improved access to *existing* housing and employment opportunities throughout the network is a main objective of transport infrastructure investment policies. The benefits of this are captured in conventional benefit-cost analysis which identifies these benefits and costs primarily through the impacts on existing users of the transport network.

Even if transport is considered as an input into other economic activities, so that the benefits of transport improvement can be extended to include the reduction in costs of other economic activities, these conventional benefits-costs calculations are confined mainly to the transport activities, and exclude the wider economic effects,

The SGEM model results reported in the previous section demonstrate that the redistributive effects do give rise to additional benefits for the NWRL project as measured by improved labour productivity and employment redistribution around the SMA alone (i.e., without needing to assume any additional growth in employment for the whole of SMA). The total improvement in labour productivity as measured by total personal income change for all of the 14 zones in the SMA is $86,284 per week (see Table 5) or $4.487 million per annum (in $2006). The conventional user benefits as estimated from TRESIS were identified earlier as $25.486 million in $2006. The total net WEI of the NWRL Project can therefore be said to amount to a 17.6% markup over conventional benefits (4.486/25.486 = 17.6%). Of this total 17.6% markup, only 2.46% (12,044*52/25,486,000 = 2.46%)[21] are really due to agglomeration effects. The rest is due to the 'general equilibrium' effects or 'wider-economy' linkages and impacts. It can be said that general equilibrium effects in the case of a spatial economy indicates the impacts (of a transport improvement project) on the level of spatial or *economic geography* efficiency, whereas agglomeration effects measures the impacts arising from the utilisation of spatial *economies of scale* (agglomeration) which are *additional* to this pure improvement in (spatial) efficiency.

5. Conclusions

An integrated model system known as TRESIS-SGEM has been developed that has a detailed behavioural system at the transport sectoral level that accounts for the interrelationship between transport and location choices of individuals and households (TRESIS), and a spatial computable general equilibrium model developed for the Sydney Metropolitan Area (Sydney General Economic Model or SGEM) that can identify a number of economy wide impacts of specific transport policies and strategies. The ability to combine these two models in an integrated model approach is critical in delivering a capability to establish the additional (or mark up) benefits of transport investment. Given the special challenge in justifying public transport projects on traditional (sectoral) benefit-cost grounds, any additional benefits

[21] See Table 7 for a decomposition of total WEIs into GE and agglomeration effects.

attributable to wider economy impacts (WEI) might make a difference in determining whether such project ideas are economically justifiable.

To demonstrate how our integrated TRESIS-SGEM model system works, it has been applied to the assessment of the proposed NWRL Project in Sydney's outer suburbs. The key finding is that there does exist additional WEIs associated with redistribution of employment activities, as well as gains in labour productivity linked to agglomeration effects arising from these redistributions. These WEIs are close to 18 percent of the traditional user benefits calculated for transport projects. The estimated WEIs estimated in this study relate only to the redistribution of employment activities and the changes in labour and is conservative as it does not include any additional benefits arising from an overall growth in economic activities and employment or opportunities arising from interaction between the local economies of the SMA with the wider economies of the rest of the state or national economies.

An interesting, and potentially important policy finding, is that 'alternative' transport investment projects may in fact be supplements or *complements* rather than competing *substitutes* if overall and total *network* effects are taken into consideration, as opposed to separately and myopically considering only the individual *links* effects.

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