Northumbria University NEWCASTLE

Ex-Post Evaluation of Economic Infrastructure Assets: The Significance of Regional Heterogeneities in Australia

Henry J. Liu[1], Peter E.D. Love[2], Michael C.P. Sing[3] and Jim Smith[4]

Abstract

The process of evaluation is pivotal for ensuring infrastructure assets meet the demands and needs of business and the wider community. An empirical *ex-post* evaluation of the impact of regional heterogeneities for economic infrastructure assets in Australia is undertaken using a panel error correction model. The paper provides governments with an invaluable insight into the nature of ex-post evaluation, which is needed to develop and implement new performance measures to improve the public sector's ability to future-proof their infrastructure assets.

Keywords: Evaluation, infrastructure, project outcome, regional heterogeneities, Australia

Introduction

Evaluation is acknowledged as a critical mechanism for ensuring organizational success and it has been widely used in a variety of industrial sectors. Infrastructure assets are typically examined using *ex-post* evaluation; this is a product-oriented or input-output measurement process that is grounded on the 'Iron Triangle' (e.g., time, cost and quality) (e.g., Haskins *et al.* 2002; Pakkala, 2002; National Audit Office, 2003; Fitzgerald, 2004; Liautaud, 2004; Sachs *et*

[1] Ph.D., Senior Lecturer, Department of Architecture and Built Environment, Northumbria University, Sutherland Building, City Campus, Newcastle upon Tyne, Tyne & Wear, NE1 8ST, United Kingdom, Email: henry.liu@northumbria.ac.uk
[2] D.Sc., Ph.D., John Curtin Distinguished Professor, School of Civil and Mechanical Engineering, Curtin University, GPO Box U1987, Perth, WA 6845, Australia, Email: p.love@curtin.edu.au
[3] Ph.D., MASCE, Research Assistant Professor, Department of Building and Real Estate, The Hong Kong Polytechnic University, Hung Hum, Kowloon, Hong Kong, Email: michael.sing@polyu.edu.hk
[4] Ph.D., Professor, School of Sustainable Development and Architecture, Bond University, 14 University Dr, Robina, QLD 4226, Australia, Email: jismith@bond.edu.au

al., 2005; Raisbeck *et al.*, 2010). An input-output evaluation approach is an ineffective measurement mechanism for assessing the performance of infrastructure projects, as it is unable to capture their inherent complexities (Yuan *et al.*, 2009; Haponava and Al-Jibouri, 2010; 2012; Liu *et al.*, 2015a,b). There is, therefore, a need to evaluate infrastructure assets from not only an input-or-output-oriented assessment but also its impact on the local region or community (Lipsey, 2000; Sharpe, 201; Liu *et al.*, 2014; Liu *et al.*, 2016a).

Infrastructure relates to the physical facilities or assets essential to forming and supporting human societies (e.g., railways, ports, hospital and stadiums) (Graham and Marvin, 2001). Hence, evaluating an infrastructure asset should consider not only how to satisfy local demand for public service, but also whether the built asset can significantly affect the development of its society (Baccarini, 1999). However, the levels of infrastructure demand and development vary and are distinct by regions due to political, economic, social, legal and demographic differences, which are referred to as regional heterogeneities (Mouquet *et al.*, 2006; Bronzini, and Piselli, 2009). With this in mind, the heterogeneity across regions should be pivotal for developing and evaluating infrastructure. The Victorian Auditor-General (2013), for example, supports this perspective by stating that a sequence of factors can contribute to the decision-making of infrastructure development, and regional heterogeneities need to be addressed throughout an assets life-cycle.

Despite the need to incorporate regional heterogeneities (e.g., population, environment and economic conditions) when evaluating the performance of infrastructure, it has received limited attention in the extant literature. Studies that have been undertaken have focused on incorporating heterogeneity into the econometric modelling of the impact of transportation infrastructure on a local economy (e.g., Agbelie, 2014; Agbelie *et al.*, 2017) and residential markets (Liu and London, 2010; 2011; Ma and Liu, 2013; 2014; Jiang and Liu, 2014; Jiang *et al.*, 2014). Nevertheless, questions surrounding why regional heterogeneities need to be considered and how they significantly affect the evaluation of assets have not been empirically examined. Against this contextual backdrop, the research presented in this paper aims to identify the significance of regional heterogeneities using an economic infrastructure evaluation framework. A panel *error correction model* (ECM) is developed with data derived from economic infrastructure assets (e.g., roads, ports, bridges, airports and electrical power supply stations) that have been constructed in Australia.

Infrastructure Evaluation

Evaluation is a process designed and implemented to quantify and report the effectiveness and efficiency of the actions taken towards an organization's objectives or strategies (Neely *et al.*, 2005). Program theory states a comprehensive evaluation encompasses inputs, processes, outputs and outcomes (Rossi *et al.*, 2004). An 'outcome' in terms of evaluation refers to the achievement of an organization's strategic goals or objectives (Baccarini, 1999; European Investment Bank, 2003). Infrastructure projects are large-scale investments with particular goals that relate to economic and/or social development; therefore, measurement for outcomes is imperative for ensuring the life-cycle success of the built assets (European Commission, 2003).

It has been argued by Reynolds (1998) that outcome evaluation needs to be undertaken during the process of infrastructure development and during an asset's operation. Essentially, investing and developing infrastructure needs to be based on local demand for public services (Melo *et al.*, 2013; Ansar *et al.*, 2016; Li, 2017). Thus, regional heterogeneity is conceptually capable of influencing the development process of infrastructure projects (Mouquet *et al.*, 2006;

Bronzini and Piselli, 2009; Victorian Auditor-General, 2013), particularly during their evaluation process whereby the actual circumstances of local communities or regions are considered and assessed (Nicolaisen and Driscoll, 2014). The theoretical framework developed by Wu *et al.* (2016) supports this perspective as it places emphasis on understanding of local conditions (e.g., population growth, economic conditions, urbanisation and regulatory systems) and therefore is critical for ensuring value for money (V*f*M) is obtained and the successful development and implementation of infrastructure assets.

Outcome Evaluation Framework of Economic Infrastructure Projects

Economic infrastructure provides human society with important fiscal drivers to harness their well-being (Graham and Marvin, 2001). Gross Domestic Product (GDP) and the employment rate are key economic indicators that can be used to assess a local macroeconomic climate (Rossana, 2011). Furthermore, an effective *ex-post* evaluation for the product success of economic infrastructure assets needs to refer to their impacts on local GDP and employment, as the aim of infrastructure development is to facilitate economic or social wellbeing (Baccarini, 1999; Liu *et al.*, 2015c; Hughes and Healy, 2014). Liu *et al.* (2015) and Sing *et al.* (2015) further support this perspective by identifying and adopting aforementioned two economic indicators for the econometric modelling of Public-Private Partnerships (PPPs) and infrastructure construction outputs of Australia and Hong Kong respectively. With perspectives in mind, an outcome evaluation framework for economic infrastructure is presented in Figure 1. Here the public sector can evaluate their economic infrastructure projects and initiate actions to ameliorate their assets' performance by examining and analysing the product's impact using two leading indicators (e.g., local GDP and employment).

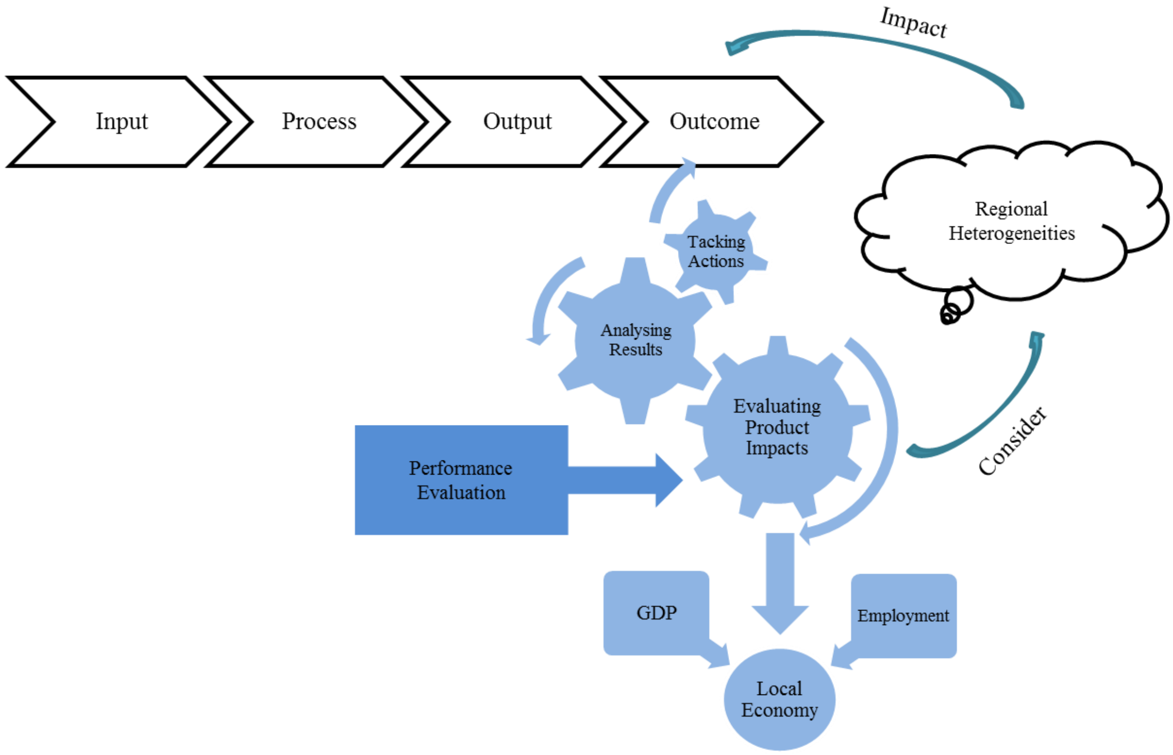

Figure 1. Outcome evaluation framework of economic infrastructure assets

Panel Error Correction Model

An ECM is developed for the conceptual framework proposed in Figure 1. In essence, regional heterogeneities are difficult to empirically observe as they tend to be intangible, though they maintain active roles in various economic sectors (Tu, 2000; Reed, 2001). However, econometric techniques based on the panel data can quantify the intangible effects that are specific to the heterogeneities within cross-sectional units (i.e., regions) across periods (Hsiao, 2003). Panel econometric models are robust in capturing the inside information of data with regard to regional heterogeneity (Greene, 2000). In addition, the ECM possesses a strong ability to identify causal linkages and correlations between variables, as pairwise regression can significantly reduce collinearity (Liu and London, 2011; Ma and Liu, 2013). A panel ECM is formulated as Eq. (1) and (2).

$$\Delta Y_{i,t} = \mu_i + \beta_i \Delta X_{i,t} + \phi_i ecm_{i,t-1} \ (i = 1,2,3...,N; \ t = 1,2,3...,T) \qquad \text{[Eq.1]}$$

$$ecm_{i,t-1} = Y_{i,t-1} - \alpha_0 - \alpha_1 X_{i,t-1} \qquad \text{[Eq.2]}$$

where $\Delta Y_{i,t}$ and $\Delta X_{i,t}$ represent the panel data $Y_{i,t}$ and $X_{i,t}$ at the first difference; μ_i and β_i stand for the regression parameters; ϕ_i is expressed as a negative value and denotes the rapidity of adjusting to equilibrium; and $ecm_{i,t-1}$ represents the error correction term, in which α_0 and α_1 in Eq. (2) are constant items with long-term elasticity respectively. The error correction term can be derived from the residuals yielded by a simple regression of two observed variables.

Data Sources

The panel data used for the purposes of the econometric modelling is derived from the Australian Bureau of Statistics (ABS) for the period 1990 to 2016 (ABS, 2016a,b). Six Australian states and two territories are examined (e.g., New South Wales – NSW, Victoria – VIC, Queensland – QLD, South Australia – SA, Western Australia – WA, Tasmania – TAS, Northern Territory – NT, and Australian Capital Territory – ACT). The gross state product (GSP) and totally employed persons (TEP) are obtained to measure local GDP and conditions of employment. The values of the completed construction work (CCW) in the civil engineering sector of Australia (e.g., roads, railways, bridges, and electricity supply stations) were selected to capture the impact of the procured economic infrastructure assets. These data were published by the ABS (2016c) within the section entitled "*Engineering Construction Activity*". Table 1 summarises the explanation for the data. The data used for the empirical estimation was transformed into a natural logarithm to reduce heteroscedasticity. Though, it should be noted that this may generate negative effects on the econometric modelling such as inefficient regression, an inconsistency in the covariance matrix of the estimated regression coefficients or biased standard error (Brooks, 2002).

Table 1: Explanation for data used for modelling

Data	Explanatory Note	Unit
GSP	The gross domestic product (GDP) within a state/territory in Australia rather than to a whole nation	AU$'000
TEP	Total employed persons within a given period	'000
CCW	The value of the completed engineering works specific for economic infrastructure assets	AU$'000

Sources: ABS (2016a,b,c)

Analysis and Findings

Akin to time-series modelling, spurious regression can be triggered if the panel data used for constructing econometric models are non-stationary (Choi, 2001). Bearing this in mind, the unit root tests proposed by Im *et al.* (2003), which is normally known as the IPS test (Im, Pesaran, and Shin - IPS), were conducted to test if the selected data was stationary (e.g., GSP, TEP and CCW). Table 2 presents the test results and indicates the inputted data are integrated of the order one, i.e., *I* (1), which implies that they are not stationary on level, but stationary after first difference. Therefore, the panel ECM in this paper will be formulated on the basis of the first-differencing data.

Table 2: Summary of the IPS unit root test results

Variables	Level			First Difference			Results
	Model Specification (Lags)	Stat.	*p*-Values	Model Specification (Lags)	Stat.	*p*-Values	
log(GSP)	Individual Intercept & Trend (1)	1.33	0.91	Individual Intercept (1)	-5.35	0.00	*I* (1)

log(TEP)	Individual Intercept & Trend (1)	0.45	0.67	Individual Intercept (1)	-6.22	0.00	*I* (1)
log(CCW)	Individual Intercept & Trend (1)	2.76	0.98	Individual Intercept (1)	-7.50	0.00	*I* (1)

The next step in constructing an ECM is to identify the co-integration between variables. Hence, the Pedroni (1999) co-integration tests were undertaken, as it is able to provide more power properties (Örsal, 2007). As indicated by equation (1), a panel ECM is a pairwise regression model; thus, Tables 3 and 4 report the results of the pairwise co-integration tests between GSP and CCW as well as TEP and CCW. Here it can be seen that long-term co-integration relationships exist in the aforementioned variables.

Table 3. Summary of the Pedroni co-integration test results between GSP and CCW

Variables	**Model Specification (Lags)**	**Panel ADF-Stat.**	***p*-Value**	**Weighted Panel ADF-Stat.**	***p*-Value (weighed)**	**Results**
log(GSP) (D.V.) log(CCW) (I.V.)	Individual Intercept (3)	-2.19	0.01	-2.83	0.00	Y

Notes: D. V. denotes the dependent variable and I. V. denotes the independent variable. "Y" denotes there is a long-run co-integration relationship between the variables.

Table 4. Summary of the Pedroni co-integration test results between TEP and CCW

Variables	**Model Specification (Lags)**	**Panel ADF-Stat.**	***p*-Value**	**Weighted Panel ADF-Stat.**	***p*-Value (weighed)**	**Results**
log(TEP) (D.V.) log(CCW) (I.V.)	Individual Intercept (3)	-1.37	0.08	-2.24	0.01	Y

Notes: D. V. denotes the dependent variable and I. V. denotes the independent variable. "Y" denotes that there is a co-integration between the variables.

After identifying co-integrations, two panel ECMs are formulated and represented as the following equations (3) and (4). These aforementioned equations identify that their cross sectional effects play a vital role in the relationships between the independent and dependent variables. More importantly, the probability values (*p*-values) of the *t*-statistics of the cross-sectional coefficients can be derived, which are all significant at 5% level. This result indicates that the heterogeneities across the states and territories of Australia are factors critical for infrastructure investment/development and need to be essentially considered during the process of *ex-post* outcome evaluation.

$$\begin{cases} \Delta GSP_{NSW,t} = 0.06 + 0.51*(\Delta CCW_{NSW,t}) - 0.12*ecm_{NSW,t-1} \\ \Delta GSP_{VIC,t} = 0.02 + 0.43*(\Delta CCW_{VIC,t}) - 0.11*ecm_{VIC,t-1} \\ \Delta GSP_{QLD,t} = 0.14 + 0.53*(\Delta CCW_{QLD,t}) - 0.24*ecm_{QLD,t-1} \\ \Delta GSP_{SA,t} = 0.05 + 0.09*(\Delta CCW_{SA,t}) - 0.97*ecm_{SA,t-1} \\ \Delta GSP_{WA,t} = 0.11 + 0.28*(\Delta CCW_{WA,t}) - 0.22*ecm_{WA,t-1} \\ \Delta GSP_{TAS,t} = -0.08 + 0.19*(\Delta CCW_{TAS,t}) - 0.16*ecm_{TAS,t-1} \\ \Delta GSP_{NT,t} = -0.09 + 0.07*(\Delta CCW_{NT,t}) - 0.27*ecm_{NT,t-1} \\ \Delta GSP_{ACT,t} = -0.02 + 0.06*(\Delta CCW_{ACT,t}) - 0.19*ecm_{ACT,t-1} \end{cases} \quad \text{[Eq. 3]}$$

$$\begin{cases} \Delta TEP_{NSW,t} = 0.07 + 0.16*(\Delta CCW_{NSW,t}) - 0.31*ecm_{NSW,t-1} \\ \Delta TEP_{VIC,t} = 0.01 + 0.24*(\Delta CCW_{VIC,t}) - 0.22*ecm_{VIC,t-1} \\ \Delta TEP_{QLD,t} = 0.17 + 0.21*(\Delta CCW_{QLD,t}) - 0.13*ecm_{QLD,t-1} \\ \Delta TEP_{SA,t} = 0.06 + 0.19*(\Delta CCW_{SA,t}) - 0.13*ecm_{SA,t-1} \\ \Delta TEP_{WA,t} = 0.05 + 0.28*(\Delta CCW_{WA,t}) - 0.28*ecm_{WA,t-1} \\ \Delta TEP_{TAS,t} = -0.02 + 0.07*(\Delta CCW_{TAS,t}) - 0.35*ecm_{TAS,t-1} \\ \Delta TEP_{NT,t} = 0.02 + 0.15*(\Delta CCW_{NT,t}) - 0.29*ecm_{NT,t-1} \\ \Delta TEP_{ACT,t} = -0.01 + 0.11*(\Delta CCW_{ACT,t}) - 0.39*ecm_{ACT,t-1} \end{cases} \quad \text{[Eq. 4]}$$

Implication of Model Reliability

Apart from the findings derived from the coefficients relating to the cross-sectional effects, Tables 5 and 6 indicate the *t*-statistics and probability values (*p*-values) of the coefficients of the independent variables (i.e., CCW) of each State and Territory in Australia. It is noted from this empirical evidence that the coefficients of NSW, VIC, QLD, and WA are positive and significant in both equations (3) and (4). Causal relationships between the variables of an error correction model if the coefficients of independent variables are significant (i.e., at 1%, 5% or 10% level) (Luo *et al*., 2007). Accordingly, the built assets of the procured economic infrastructure projects in the aforementioned states had causally and substantially affected the local economic developments during the observed period (i.e., 1990 to 2016).

Table 5. The *t*-Statistic and *p*-Value of the coefficients of the independent variables in Eq. (3)

Variables	*t*-Statistic/Coefficients	*p*-Values
$\Delta CCW_{NSW,t}$	4.87 (0.51)	0.00
$\Delta CCW_{VIC,t}$	3.82 (0.43)	0.00
$\Delta CCW_{QLD,t}$	4.88 (0.53)	0.00
$\Delta CCW_{SA,t}$	0.56 (0.09)	0.57
$\Delta CCW_{WA,t}$	2.85 (0.28)	0.01
$\Delta CCW_{TAS,t}$	1.08 (0.19)	0.28
$\Delta CCW_{NT,t}$	1.13 (0.07)	0.26
$\Delta CCW_{ACT,t}$	0.53 (0.06)	0.60

Table 6. The *t*-Statistic and *p*-Value of the coefficients of the independent variables in Eq. (4)

Variables	*t*-Statistic/Coefficients	*p*-Values
$\Delta CCW_{NSW,t}$	1.75 (0.16)	0.08
$\Delta CCW_{VIC,t}$	1.66 (0.24)	0.09
$\Delta CCW_{QLD,t}$	2.02 (0.21)	0.05
$\Delta CCW_{SA,t}$	0.87 (0.19)	0.39
$\Delta CCW_{WA,t}$	3.22 (0.28)	0.00
$\Delta CCW_{TAS,t}$	0.51 (0.07)	0.61
$\Delta CCW_{NT,t}$	1.03 (0.15)	0.31
$\Delta CCW_{ACT,t}$	0.90 (0.11)	0.37

The findings presented in Tables 5 and 6 above suggests that the outcome of the procured economic infrastructure projects in NSW, VIC, QLD and WA were of significant benefit to the community. The average total values of the transport projects completed in NSW, VIC and QLD was a staggering AU$300 billion, in comparison to the other states (e.g., SA, TAS, NT and ACT) (ABS, 2017). Furthermore, NSW, VIC and QLD led the way in delivering infrastructure assets using PPPs (Taseska, 2008). The average total values of PPP economic infrastructure projects procured in each of these four states between 1990 and 2016 was AU$57 billion, where as in SA, TAS, NT and ACT it was about AU$7 billion only (ABS, 2016b).

PPPs are capable of providing not only cost efficiency, but also non-financial benefits for example, clearly defined governance structure, accelerated and early delivery, high level of service quality, assured maintenance, innovation and fiscal programming, particularly in the mature markets such as Australia (Yong, 2010). Similarly, the European Investment Bank (2011) has suggested that PPPs can provide wider social and economic impacts on labour markets and macroeconomic environments, though the nature of the outcome is similar to those assets delivered using other procurement methods. Thus, the promotion and widespread use of PPPs in NSW, VIC and QLD may have positively contributed to enhancing the economic benefits provided by the infrastructure assets to the local economies.

The state economy of WA has been traditionally dominated by the resources and energy sectors and driven by the export of iron and natural gas. According to the ABS (2016a), WA accounted for more than 40% of Australia's total export in 2011. To efficiently transport mining products and stimulate economic growth, the WA state government provided a commitment to invest approximately $122 billion over a five-year period (Department of State Development, 2014; Minister for Infrastructure and Regional Development, 2014).

The impacts in terms of SA, TAS, NT and ACT, as indicated in Tables 5 and 6, are insignificant. Several studies have indicated there has been insufficient investment in economic infrastructure in SA, TAS, NT and ACT over past decade (Bureau of Infrastructure, Transport and Regional Economics - BITRE, 2008; McTaggart *et al.*, 2013; Government of South Australia, 2014). The empirical findings generated by the panel ECMs complied with the actual economic infrastructure development that occurred in the Australian eight states that were examined. The economic models presented in this paper are deemed to be reliable. As a result, governments can use the implications derived from the model to develop effective mechanism to determine how their investments will influence a region and used to support policy development. Having in place an approach that can be used objectively evaluate infrastructure investment provide policy-makers with confidence that they are regional areas will be economic benefits that have been traditionally difficult to quantify.

Conclusions

This paper has identified and empirically examined the significance of regional heterogeneity in outcome evaluation by using data derived from economic infrastructure projects undertaken in Australia. The empirical evidence derived from two panel ECM models indicate that the heterogeneities across regions resulting from local variations (e.g., political, economic, social and/or demographic) are significant and should be considered and addressed as part of an outcome evaluation for infrastructure development. The results indicate that the procured economic infrastructure assets in the States of NSW, VIC, QLD and WA positively and substantially influenced the leading economic indicators of the local economy, while the impact on regional economic development is insignificant in four other States and Territories (e.g., SA, TAS, NT, and ACT). These findings reflect and represent the current economic conditions existing Australia and therefore validate the developed framework and models.

This research is theoretically significant. It contributes to the literature through an examination of the significance of regional heterogeneity, which has received very limited attention within the context of infrastructure. To address this void, a novel ex-post evaluation framework for economic infrastructure assets has been developed in this paper to determine how investment impacts regions and therefore enabling the public sector with the knowledge to engender a policy of future-proofing to take place. Owing to the unavailability of sufficient time-series data on economic infrastructure in Australia, limited independent variables were incorporated into modelling in this study. This is a research limitation. Thus, future research should focus on identifying the types of heterogeneities as well as their determinants and relevant longitudinal data across regions and/or communities that are particularly important for an infrastructure evaluation (e.g., political, economic, social or demographic differences).

Data Availability Statement

Data that have been used for the econometric modelling of this study are published by the *Australian Bureau of Statistics*. They can be retrieved by accessing the official website of the Australian Bureau of Statistics and full references have been provided in the following reference list.

References

Agbelie, B.R.D.K. (2014). "An empirical analysis of three econometric frameworks for evaluating economic impacts of transportation infrastructure expenditures across countries." *Transport Policy*, 35, 304-310.

Agbelie, B.R.D.K., Chen, Y., Salike, N. (2017). "Heterogeneous economic impacts of transportation features on prefecture-level Chinese cities." *Theoretical Economics*

Letters, 3(7), 339-351.

Ansar, A., Flyvbjerg, B., Budzier, A. and Lunn, D. (2016). “Does infrastructure investment lead to economic growth or economic fragility? Evidence from China.” *Oxford Review of Economic Policy*, 32(3), 360-390.

Australian Bureau of Statistics (ABS) (2016a). “Australian national accounts: State accounts, 2013-14.” < http://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/5220.02013-14 ?OpenDocument> (accessed 23 November 2016).

Australian Bureau of Statistics (ABS) (2016b). “Engineering construction activity, Australia, Mar 2014.” <http://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/8762.0Mar%2 02014?OpenDocument> (accessed 23 November 2016).

Australian Bureau of Statistics (ABS) (2016c). “Labour force, Australia, Detailed, Quarterly, May 2014.” <http://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/6291.0.55.003 May%202014?OpenDocument> (accessed 23 November 2016).

Baccarini, D. (1999). “The logical framework method for defining project success.” *Project Management Journal*, 30(4), 26-32.

Bronzini, R. and Piselli, P. (2009). “Determinants of long-run regional productivity with geographical spillovers: the role of R&D, human capital and public infrastructure.” *Regional Science and Urban Economics*, 39(2), 187-199.

Brooks, C. (2002). *Introductory econometrics for finance*, Cambridge University Press, UK.

Bureau of Infrastructure, Transport and Regional Economics (BITRE) (2008). "A regional economy: A case study of Tasmania." Report 116, Canberra, ACT, Australia.

Choi, I. (2001). "Unit root tests for panel data." *Journal of International Money and Finance*, 20(2), 249-271.

Department of State Development (2014). "Economic infrastructure." < http://www.dsd.wa.gov.au/invest-in-wa/sector/economic-infrastructure/transport> (accessed Jan 23, 2015).

European Commission (2003). "Guidelines for successful public-private partnerships." European Commission, Brussels, Belgium.

European Investment Bank (2003). "Evaluation of the impact of EIB financing on regional development in Greece." European Investment Bank, Luxembourg.

European Investment Bank (2011). "The non-financial benefits of PPPs: An review of concepts and methodology." European Investment Bank, Luxembourg.

Fitzgerald, P. (2004). "Review of partnerships Victoria provided infrastructure." Final Report to the Treasurer, Growth Solutions Group, Melbourne, Australia.

Government of South Australia (2014). "South Australian regional mining and infrastructure plan". Report to Government of South Australia, Adelaide, Australia.

Graham, S. and Marvin, S. (2001). *Splintering urbanism*, Routledge, London, UK.

Greene, W.H. (2000). *Econometric analysis*, 4th ed., Prentice-Hall, New Jersey, USA.

Haponava, T. and Al-Jibouri, S. (2010). "Influence of process performance during the construction stage in achieving end-project goals." *Construction Management and Economics*, 28(8), 853-869.

Haponava, T. and Al-Jibouri, S. (2012). "Proposed system for measuring project performance using process-based key performance indicators." *Journal of Management in Engineering*, 28(2), 140-149.

Haskins, S., Gale, D. and Kelly, L. (2002). "Creating and optimizing new forms of public-private partnerships in Seattle." *Water Science Technology: Water Supply*, 2(4), 211-218.

Hsiao, C. (2003). *Analysis of panel data*, Cambridge University Press, UK.

Hughes, J.F. and Healy, K. (2014). "Measuring the resilience of transport infrastructure." NZ Transport Agency Research Report 546, 82pp, New Zealand.

Im, K.S., Pesaran, M.H. and Shin, Y. (2003). "Testing for unit roots in heterogeneous panels." *Journal of Econometrics*, 115(1), 53-74.

Jiang, H. and Liu, C. (2014). "A panel vector error correction approach to forecasting demand in regional construction markets." *Construction Management and Economics*, 32(12), 1205-1221.

Jiang, H., Xu, Y. and Liu, C. (2014). “Market effect on forecasting construction price using vector error correction models.” *International Journal of Construction Management*, 14(2), 101-112.

Liautaud, G. (2004). “Maintaining roads: experience with output-based contracts in Argentina.” The World Bank, Washington, D. C., US.

Lipsey, M.W. (2000). “Evaluation methods for social intervention.” *Annual Review of Psychology*, 51, 345-375.

Liu, J. and London, K. (2010). “New Housing Supply and Residential Construction Costs in Australia: A Panel ECM Approach.” *Refereed Proceedings of the 17th Pacific Rim Real Estate Society Annual Conference*, 16-19 January 2011, Gold Coast, Australia.

Liu, J. and London, K. (2011). “Analysing the relationship between new housing supply and residential construction costs with regional heterogeneities.” *Construction Economics and Building*, 11(3), 58-67.

Liu, J., Love, P.E.D., Carey, B., Smith, J. and Regan, M. (2015a). “Ex-ante evaluation of Public-Private Partnerships: Macroeconomic analysis.” *Journal of Infrastructure Systems*, 10.1061/(ASCE)IS.1943-555X.0000228.

Liu, J., Love, P.E.D., Davis, P.R., Smith, J. and Regan, M. (2015b). “Conceptual framework for the performance measurement of public-private partnerships." *Journal of Infrastructure Systems*, 10.1061/(ASCE)IS.1943-555X.0000210, 04014023.

Liu, J., Love, P.E.D., Smith, J., Regan, R. and Davis, P.R. (2015c). "Life cycle critical success factors for Public-Private Partnership infrastructure projects.", *Journal of Management in Engineering*, doi.org/10.1061/(ASCE)ME.1943-5479.0000307.

Liu, J., Love, P.E.D., Sing, M.C.P., Smith, J. and Matthews, J. (2016a). "PPP social infrastructure procurement: Examining the feasibility of a life-cycle performance measurement framework." *Journal of Infrastructure Systems*, 10.1061/(ASCE)IS.1943 -555X.0000347.

Liu, J., Love, P.E.D., Smith, J., Matthews, J. and Sing, C. (2016b). "Praxis of performance measurement in Public-Private Partnerships: Moving beyond the Iron Triangle." *Journal of Management in Engineering*, 10.1061/(ASCE)ME.1943-5479.0000433.

Liu, J., Love, P.E.D., Smith, J., Regan, M. and Palaneeswaran, E. (2015c). "Review of performance measurement: implications for public-private partnerships." *Built Environment Project and Asset Management*, 5(1), 35-51.

Liu, J., Love, P.E.D., Smith, J., Regan, M. and Sutrisna, M. (2014). "Public-private partnerships: A review of theory and practice of performance measurement". *International Journal of Productivity and Performance Management*, 63(4), 499-512.

Love, P.E.D., Liu, J., Matthews, J., Sing, C.P. and Smith, J. (2015). "Future proofing PPPs:

Life-cycle performance measurement and building information modelling." *Automation in Construction*, 56, 26-35.

Luo, Z.Q., Liu, C. and Picken, D. (2007). "Housing price diffusion pattern of Australia's state capital cities." *International Journal of Strategic Property Management*, 11(4), 227-242.

Ma, L. and Liu, C. (2013). "A panel error correction approach to explore spatial correlation patterns of dominant housing market in Australian capital cities." *International Journal of Housing Markets and Analysis*, 6(4), 405-421.

Ma, L. and Liu, C. (2014). "A spatial decomposition approach for investigating house price convergences." *Australian Journal of Regional Studies*, 20(3), 487-511.

McTaggart, D., Smith, I., and Henderson, P. (2013). "Recommendations for the Northern Territory Government's economic development strategy". Economic Development Advisory Panel, Department of the Chief Minister, < http://www.dcm.nt.gov.au/_data/assets/pdf_file/0004/62797/Recommendations_for_the_NTG_Economic_Development_Strategy.pdf) (accessed Jan 23, 2015).

Melo, P. C., Graham, D. J. and Brage-Ardao, R. (2013). The productivity of transport infrastructure investment: A meta-analysis of empirical evidence. *Regional Science and Urban Economics*, 43(5), 695-706.

Minister for Infrastructure and Regional Development (2014). "Building Western Australia's transport infrastructure for the 21st century". <http://www.minister.infrastructure.gov.a

u/wt/releases/2014/May/budget-infra_07-2014.aspx> (accessed Jan 23, 2015).

Mouquet, N., Miller, T. E., Daufresne, T., and Kneitel, J. M. (2006). "Consequence of varying regional heterogeneity in source – sink metacommunities." *OIKOS*, 113(3), 481-488.

National Audit Office (2003). "PFI: construction performance." Report by the Comptroller and Auditor General, HC 371, Session 2002-03, London, UK.

Neely, A., Gregory, M. and Platts, K. (2005). "Performance measurement system design: a literature review and research agenda." *International Journal of Operations and Production Management*, 25(12), 1228-1263.

Örsal, D.D.K. (2007). "Comparison of panel cointegration tests". SFB 649 Discussion Paper, 2007-029, Humboldt-Universität zu Berlin, Berlin, Germany.

Pakkala, P. (2002). "Innovative project delivery methods for infrastructure." Finnish Road Enterprise, Helsinki, Finland.

Pedroni, P. (1999). "Critical values for cointegration tests in heterogeneous panels with multiple regression." *Oxford Bulletin of Economics and Statistics*, 61(4), 653-670.

Raisbeck, P., Duffield, C. and Xu, M. (2010). "Comparative performance of PPPs and traditional procurement in Australia." *Construction Management and Economics*, 28(4), 345-359.

Reed, R. (2001). "The significance of social influences and established housing values." *Refereed Proceeding in the 7th Pacific Rim Real Estate Society Conference*, Adelaide, Australia.

Reynolds, A.J. (1998). "Confirmatory program evaluation: A method for strengthening causal inference." *American Journal of Evaluation*, 19(2), 203-221.

Rossana, R.J. (2011). *Macroeconomics*, Routledge, New York, USA.

Rossi, P.H., Lipsey, M.W. and Freeman, H.E. (2004). *Evaluation: A systematic approach*, 6th ed., Sage Publication, Thousand Oaks, USA.

Sachs, T., Elbing, C., Tiong, R.L.K. and Alfen, H. (2005). "Efficient assessment of value for money (VFM) for selecting effective public private partnership (PPP) solutions – A comparative study of VFM assessment for PPPs in Singapore and Germany." Nanyang Technological University, Singapore.

Sharpe, G. (2011). "A review of program theory and theory-based evaluations." American *International Journal of Contemporary Research*, 1(3), 72-75.

Taseska, A. (2008). "Overview of public private partnerships in Australia: Financing, regulation, auditing and proposed improvements." *The Journal of Contemporary Issues in Business and Government*, 14(2), 79-90.

Tu, Y. (2000). "Segmentation of Australian housing markets: 1989-98." *Journal of Property*

Research, 17(4), 311-327.

Victorian Auditor-General (2013). “Developing transport infrastructure and services for population growth areas.” PP No. 249, Session 2010-13, Melbourne, Australia.

Yong, H.K. (2010). *Public-private partnerships policy and practice*, Commonwealth Secretariat, London, UK.

Yuan, J., Zeng, A.Y., Skibniewski, M.J. and Li, Q. (2009). “Selection of performance objectives and key performance indicators in public-private partnership projects to achieve value for money.” *Construction Management and Economics*, 27(3), 253-270.