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

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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*

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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).

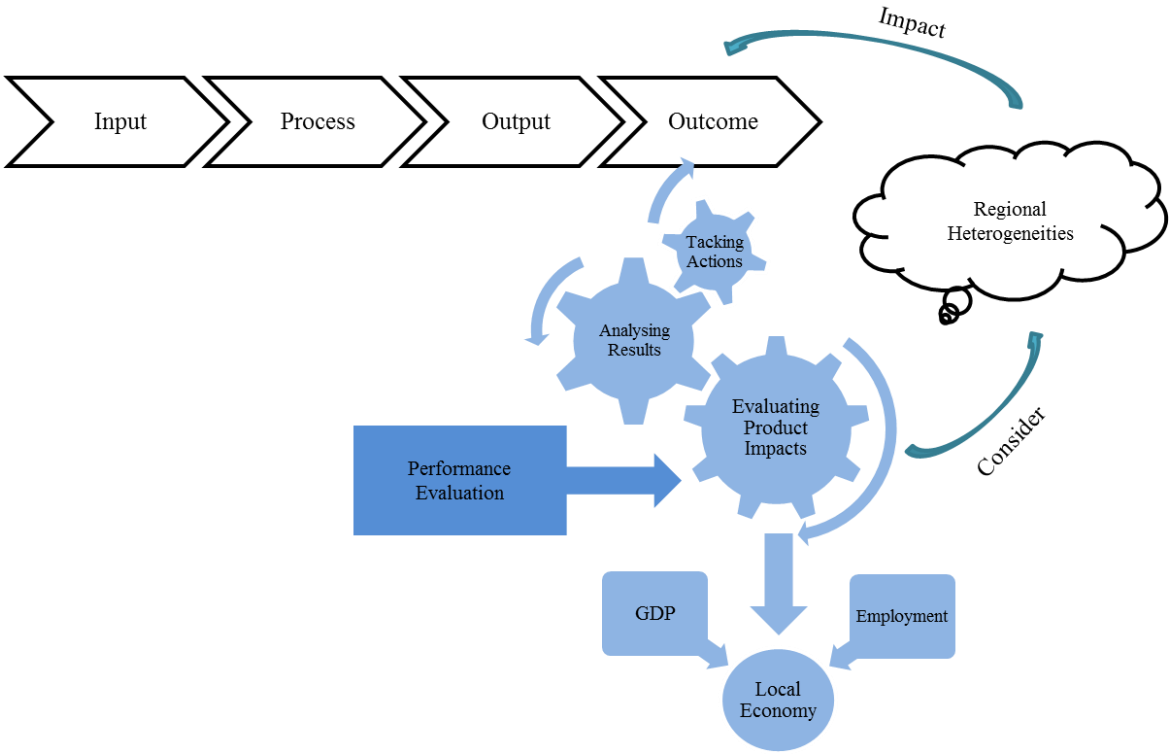

Figure 1. Outcome evaluation framework of economic infrastructure assets

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).

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

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

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.

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