Using an Evolutionary Model to Explain Gaps in Infrastructure Investment by Municipal Governments in Australia

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Abstract

Shortfalls in infrastructure expenditure represent a ubiquitous problem in all Australian local government systems as well as in many other countries. In this paper we use an evolutionary model to describe how local government investment decisions are made. We demonstrate that fear of reputational damage among elected councilors could cause herding behavior resulting in convergent and overly cautious investment behavior by councils. Under these conditions divergent viewpoints amongst council members are discouraged and local government may become moribund in its decision-making. We show how this may result in 'gaps' in infrastructure investment.

JEL Classification codes: D72, H70, D80

Keywords: local government, infrastructure, herding behavior

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I Introduction

In common with most other nations, all Australian state and territory local government systems face acute problems with local infrastructure as a consequence of ongoing under-investment not only in the provision of new infrastructure, but also in the maintenance of existing infrastructure (Dollery, Kortt and Grant, 2013). As a rule, local government has contended that its straitened financial conditions have forced it to reduce local infrastructure investment and maintenance to sustain current service provision. The inevitable result has been a significant and mounting local infrastructure shortfall in all Australian local government systems. This has been repeatedly acknowledged in numerous Australian state and national public inquiries.

An embryonic academic literature has considered the infrastructure backlog in Australian local government. In general, this literature has taken the existence of the infrastructure backlog as given and instead has concentrated on the best methods of remedying the problem. In particular, the scholarly literature has not sought an conceptual explanation for the endemic existence of local infrastructure backlogs in Australia and many other countries. In this paper we address this gap in the literature.

We argue local government infrastructure gaps may, at least in part, be due to the way in which local authorities operate, particularly in regard to how they make decisions. We use an evolutionary model to show how missing markets for risk could lead to council decision making becoming moribund and overly cautious. Our results align with the previous literature inasmuch more sophisticated funding mechanisms appear to be needed to allow better diversification of risk for these types of investments.

The paper is divided into five main parts. By way of background, section II considers the Australian local government infrastructure backlog through the prism of various state and national inquiries into local government over the past two decades, as well as a nascent academic literature on this infrastructure shortfall. Section III outlines the nature of the conceptual problem posed by the infrastructure backlog whereas section IV proposes a simple model to tackle the problem. Section V presents the results of a simple algorithm process. The paper concludes in section VI with a brief assessment of its main implications.

II Australian Local Government Infrastructure Backlog

In the absence of comprehensive and reliable national data on local government infrastructure maintenance and renewal, in Australia, in its *National Financial Sustainability Study of Local Government* PriceWaterhouseCooper (PWC) (2006) sought to calculate national estimates of the local infrastructure shortfall. In essence, PWC (2006) employed two methods of measuring infrastructure under-investment. In the first place, financial data was drawn from a weighted and stratified national sample of 100 local councils across all seven Australian municipal classification categories. This data was compared against Key Performance Indicators (KPIs) which were designed to proxy financial sustainability. PWC (2006) determined that a considerable percentage of local authorities needed external financial assistance to stay fiscally viable. Secondly, PWC (2006) estimated the size of the local infrastructure gap by extrapolating trends from New South Wales, South Australia and Western Australia originally developed by

Access Economics (2006a; 2006b), as well as deploying information on Victorian local government taken from the Municipal Association of Victoria (MAV) (2005). This accounted for 63 per cent of all Australian local authorities, 72 percent of all local roads as well as 76 percent of the Australian population (PWC, 2006, p.9).

In order to accommodate the uncertainties in the available data, which prevent the direct comparison of state-specific estimates, PWC (2006) computed three measures of the Australian local government infrastructure shortfall: a ‘mean estimate’, an ‘upper estimate’ and a ‘lower estimate’. These were extrapolated from the ‘core’ states in the PWC (2006) sample data to incorporate Queensland, Tasmania and Northern Territory. This yielded the three aggregate national estimates outlined in Table 1.

INSERT TABLE 1 HERE

Table 1 shows a national municipal infrastructure shortfall, extending from $12.0 billion at the lower end to a $15.3 billion upper estimate, with an annual expenditure deficit of between $0.9 billion to $1.2 billion. This indicates that between $1.8 billion and $2.3 billion per annum is required to assuage the current deficit in infrastructure maintenance and investment disbursements. This is equivalent to some $2.6 million and $3.3 million per council annually (Dollery & Mounter, 2010).

In addition, PWC (2006) computed the anticipated financial burden on local residents of tackling the infrastructure shortfall. Table 2 contains estimates of the impost on residents which would average $2.6 million per council, or about $87 to $109 per resident annually.

INSERT TABLE 2 HERE

However, the estimates in Table 1 and Table 2 should be treated with care due to data deficiencies and data inconsistencies. Moreover, the estimates established in the FSRB Report (2005), the Allan Report (2006), LGAQ Report (2006), WALGA Report (2006), and the LGAT (2007) should also be used with caution (Dollery & Mounter, 2010). However, despite these these uncertainties, there seems little doubt that a serious despite Australian local government local infrastructure funding crisis exists.

In addition to these national and state inquiries, as well as work by commercial consultants, like Ernst & Young (2012), nascent scholarly literature has examined the Australian local government infrastructure backlog (see Dollery, Kortt & Grant (2013) for a detailed review of this literature). This literature has *inter alia* considered alternative approaches to remediating the infrastructure shortfall by councils borrowing private sector funds. For instance, Byrnes, Dollery, Crase &Simmons (2008) called for the establishment of an Australian municipal bond market, along analogous lines to the American 'muni market'. Similarly, Dollery, Byrnes & Crase (2007a) have argued for an Australian federal infrastructure fund for municipal infrastructure funding. Finally, Dollery, Kortt & Grant (2011; 2012) suggested the creation of a national bond bank to pool individual council risk in aggregated infrastructure bonds issues guaranteed by the Australian Government.

III Conceptual Problem

Investment decisions by councils are supposed to reflect a consensus of opinions held by individual councilors about social returns from specific investments (Simmons & Dollery, 2014). We argue that a consensus of this kind may be influenced by 'herding behavior' and that such behavior may cause overly cautious investment resulting in 'gaps' in council investment. In this context, herding behavior is defined as an obvious intent to copy the behavior of others even to the extent that individual or social ends may be ignored. Herding behavior may arise from sanctions on outliers, a possible driver of herding identified in Bikhchandani & Sharma, (2000[ii]) where such sanctions on outliers are analogous to an underlying evolutionary process. The type of sanction we specifically consider is reputational damage from supporting unsuccessful projects resulting in councilors appearing incompetent (Scharfstein & Stein, 1990).

The dynamic underlying our model is that councilors observe (i) which investment proposals are supported by other councilors though not the actual reasons they are supported and (ii) the *ex post* performance or outcomes of these investments in terms of acceptance by the local community or in terms of social return after implementation. Councilors then use this information to imitate decision making by other councilors if they believe those councilors are 'better' than themselves at assessing council investment proposals.

Two elements are conjectured in our modeling. The first is that councilors' opinions converge to some type of consensus over a number of investment periods. This is an outcome of our numerical analysis and corresponds to 'rational, non-spurious herding' (Bikhchandani & Sharma, 2000). The second element is the consensus that emerges from herding reflects caution or risk aversion. Our contribution in this paper is to show that the origin of this caution is herding behavior.

It then follows in a straightforward fashion that if councilors are cautious, investment levels will be ‘too low’ from a social perspective and over time an investment gap will emerge. But why should a ‘herd’ turn out to be so cautious in these circumstances? Herding theory on its own, developed to explain surges or bubbles in investment rather than deficits in investment, is unhelpful in answering this question.

Szpiro (1997) proposed that evolutionary models might be used to explain certain types of cautious behavior. He showed that agents lacking caution and unprepared to be strategic in their decision making were likely to lose in certain types of contests and that these agents will disappear from these contests leaving only the cautious agents. Cacho & Simmons (1999) applied Szpiro’s (1997) cautionary principle to a farm investment problem showing how strong ‘selection’ pressures from volatile markets involving risk of bankruptcy could result in behavior by farmers that was both cautious and non-Paretian. Simmons & Cacho (2005) applied the same principle to setting a pollution tax and discovered selection pressure by political constituents could result in taxes being set too low from a social perspective reflecting caution on the part of politicians.

The theory of cautious behavior used in these studies is fundamentally different to classical treatments based on diminishing marginal utility (von Neuman & Morgenstern, 1946). In the latter genre, agents value marginal dollars less when their incomes are high than when they are low. This causes incentives to shift income from high to low income states indicating a preference for stability. In our discussion no assumptions are made about utility functions since the results hinge entirely on strategic responses to perceived threats. Some intuition for the differences between these two approaches can be seen with a simple example. Consider the common practice at Australian beaches of swimming 'in the crowd' to avoid a shark attack. This behavior is clearly strategic since the swimmer is positioning herself in relation to other swimmers to minimize risk. Marginal utility of income is irrelevant in this type of problem.

The shark example provides further insights. As well as being cautious behavior, it is also herding behavior. Outlying swimmers are more likely to be attacked so behavior converges with everyone swimming in the same area. Second, the example encourages some philosophical conjecture. Bikhchandani et al (1992) argues economic herding may reflect a natural tendency towards conformity amongst humans. Do swimmers work out that imitating each other is a good idea or is this inherent? Have outlying swimmers been 'knocked off' by sharks over thousands of years so only conformist swimmers remain? In our council example, do councilors figure out they would be better off imitating smarter councilors or does convergence occur because outlying councilors are 'knocked off' by hostile electorates? The question is whether we are dealing with a learning theory or a Darwinian type of theory. It is pertinent since the underlying behavioral model may influence the length of time an equilibrium takes to emerge.

IV A Simple Model

There is no published work on how Australian councils arrive at investment decisions and, in fact, no reason to believe such processes would be consistent across councils, or for that matter, over time. We assume (i) individual councilors are influential in such investment decisions and (ii) a range of projects are considered with some being accepted and some rejected. We also assume councilors meet periodically and provide their opinions on the desirability of different projects and that investments are not part of specific grants or tied funding arrangements with other levels of government.

Councilors meet periodically and - faced with the necessity of funding investments from taxes or fees - accept some proposals and reject others based on how they believe the investments will perform in terms of returns to the community. Only a proportion, p, of the council's investment proposals are allocated since some of the projects are deemed not worthy of support.

More formally, the meeting collectively chooses p to maximize total return on investments, r, based on its assessment of likely total returns:

$$max_p \ r = (1-p)r_b + p\, r_e \qquad (1)$$

where $r_b > 0$ is the opportunity cost of capital, a bond rate which is assumed to be risk free, r_e is the return expected to prevail on the council's portfolio of investments and p is bounded below by zero to exclude council borrowing and above by unity to exclude shorting of assets, a practical impossibility. In this regard, r_b is a threshold return and investments expected to yield returns below it are rejected. Investment lags ensure r_e is unknown when the council chooses p. Providing expected $r_e > r_b$ and markets for risk are complete in the Diamond (1967) sense, p should equal unity for investment to be Pareto Optimal.

We assume individual councilors privately form an assessment about what values of r_e will prevail for individual investments after lags have worked themselves out. It is not necessary for councilors to actually calculate a numerical value for r_e. However, we assume their enthusiasm and support for various projects allows signals to be extracted by the meeting that contribute to the council's eventual *collective* decision about p. Some councilors are optimistic and contribute to high values of p and other councilors are pessimistic contributing to low values of p.

Over time, the performance of investments starts to be revealed and it is apparent some councilors are good at contributing to council investment decisions while others have incurred reputational damage by providing bad advice. If r_e turns out to be low, then messages from councilors that council should be conservative (low p) are, in retrospect, 'good advice.' Alternatively, if r_e turns out to be high the same recommendation appears to be 'bad advice'. Since future values of r_e are assumed to be unknowable when investment decisions are made, 'good advice' appears to depend on good luck. However, as our discussion below will show, it may not all be good luck. It turns out councilors can improve their chances of appearing to be good at providing advice through strategic behavior.

Councilors whose contributions to p would have resulted in very low values for total return, r, feel compelled to examine how they got it so wrong. At the next investment meeting they adopt some of the opinions of councilors who provided better advice than they did. Over time, advice starts to converge as councilors who 'got it right' become role models and their views start to dominate.

V Results from a Simple Algorithm

We capture the essence of this problem with a simple computer model. We start by generating a list of 20 values of p, the decision variable, that are random and uniformly distributed between zero and one. These are the individual values of p implied by the 20 councilors at their first or initial meeting. Assume r_b, the risk free rate, is 5% and that r_e, the expected return from the risky investment portfolio (conditional on information available when decisions are made) is lognormally distributed with a mean of 8% and standard deviation of 4.3%.

A value of r_e is then drawn randomly and equation (1) used to calculate 20 values of r corresponding to the 20 values of p in the initial list. The values of r are ranked from highest to lowest and the p values associated with the two lowest values of r are removed from the initial p list and replaced with new values calculated from two of the 18 surviving values of p. (The computer program randomly selects two surviving p values and averages them.) The latter step corresponds to two councilors changing their forecasts by imitating more successful peers. The other 18 councilors, whose guesses about p were not too bad, keep the same values for p going into the next round of decision making.

The computer program repeats this process in a loop for 60 periods with different drawings of r_e in each period and with two councilors changing their views about p each period and adopting some combination of the guesses about p made by two of their more successful peers. This simple loop based program is a type of evolutionary algorithm that performs in much the same way as the genetic algorithms used in Cacho & Simmons (1999) and Simmons & Cacho (2005), discussed previously. The cost of this simplification is slower convergence, not an issue here.

When the model is run holding r_e constant at 8%, p converges rapidly to one since $p = 1$ is the solution to the maximization problem in (1) when outcomes are certain and $r_e > r_b$. It turns out $r = 8\%$. However, this does not occur when r_e is uncertain, changing each period and risks cannot be offset. For example, if the investment is a flop, say r_e turns out to be 1%, then any guess of $p = 1$ would end up with a value of $r = 1\%$, a most unsatisfactory outcome for the guesser.

Table 3 reports the 20 initial values of p and the 20 values that prevailed at period 60 for a particular run of the model. The average value of p is 0.51 at period 60 and the 20 councilors' guesses about the correct value of p have almost converged to a single value. Opinions have converged over time and obviously an important lesson for survival under our assumptions is not to hold divergent views. Councilors have herded.

INSERT TABLE 3 HERE

Interestingly, different runs of the model provided different convergent values of p. This reflects the probabilistic elements in the algorithm and is consistent with the conclusion in Bikhchandani et al. (1992) that herding equilibria are likely to be very unstable. To be able to draw inferences, the model was re-run 1000 times providing an average convergent value of p of 0.69 and a standard deviation of 0.13 for mean values of p obtained in period 60 in each run. The 99 per cent confidence interval is 0.44 to 0.95. The convergence pathway for p for this aggregated result is shown in Figure 1. The average total return, r, obtained by the council turns out to be 7.3 per cent, less than maximum possible, and socially optimal, value of 8 per cent but greater than the bond rate of 5%.

This is best interpreted as a learning model. Councilors learn to be cautious and choose values of p to minimize the consequences of getting p 'wrong'. The values do not converge to the social optimum of $p = 1$. Rather, the value of p that is collectively adopted is that which provides a compromise between looking 'good' and looking 'bad' in a politically hazardous world where investment returns are uncertain and pre-conditions for herding behavior exist. The result of this caution is that there will be a 'gap' between socially optimal and actual council investment.

INSERT FIGURE 1 HERE

VI Conclusion

A different story could have been told such as councilors who were unlucky enough to get p too wrong were simply ejected from the council at election time and replaced by new councilors who anxiously looked to their more experienced and successful colleagues for guidance on appropriate values for p. Alternatively, decisions might be taken by the council using advice from consultants with the worst of these sacked on a regular basis. In addition, a few extra equations would have allowed more generous assumptions to be made about the quality of information politicians use to make decisions and, in the same vein, more realistic assumptions about how decisions are actually arrived at in these situations.

However, regardless of reinterpretation or elaboration of the model, we believe these results are essentially robust. Social or political pressure to avoid errors that results in imitative behavior is likely to cause caution as well as convergence of ideas in groups. This might easily explain how a local government, faced with an undiversified portfolio of investment proposals and without markets to offset risk, could develop a penchant for under-investing that results in infrastructure gaps. Our model also provides hints about what might be done about such gaps. If markets for risk were complete rather than missing, for example if enough benefits from infrastructure investments could be captured to attract private funding or there were instruments for swapping infrastructure risk, then markets rather than council members would be 'picking winners'. The moribund type of behavior we described would not occur and councilors might usefully apply their local knowledge to promotion of public investments on behalf of constituents.

References

Access Economics. 2006b. *Local Government Finances in Western Australia*. Research Report for the Western Australian Local Government Association. Perth: Access Economics.

Access Economics. 2006a. *Local Government Finances in NSW: An Assessment.* Research Report for the Independent Inquiry into the Financial Sustainability of NSW Local Government. Sydney: Access Economics.

Byrnes, J.D, Dollery, B. E., Crase, L. and Simmons, P., (2008), Resolving the Infrastructure Crisis in Local Government: A Bond Market Issue Approach Based on Local Council Income, *Australasian Journal of Regional Studies*, Vol. 14, No. 2, pp. 115-131.

Bikhchandani, S. and Sharma, S., (2000), Herd behavior in financial markets: a review, IMF Working Paper WP/00/48, International Monetary Fund.

Cacho, O. and Simmons, P.R., (1999), A genetic algorithm approach to farm investment, *Australian Journal of Agricultural and Resource Economics*, Vol. 43, No. 3, pp. 305-323.

Commonwealth Grants Commission (CGC) (2001), *Review of the Operation of Local Government (Financial Assistance) Act 1995*, Commonwealth Grants Commission, Canberra.

Diamond, P., (1967), The role of a stock market in a general equilibrium model with technological uncertainty, *American Economic Review*, Vol. 57, September, pp. 759-76.

Dollery, B.E., Byrnes, J.D. and Crase, L. (2007), The Infrastructure Crisis in Australian Local Government: A Proposed Federal Asset Fund Solution, *Australasian Journal of Regional Studies*, Vol. 13, No. 1, 3-19.

Dollery, B. E. and Grant, B. (2011), Financial Sustainability and Financial Viability in Australian Local Government, *Public Finance and Management*, Vol. 11, No. 1, pp. 28-47.

Dollery, B. E., Kortt, M. A. and Grant, B. (2011), Tackling the Australian Local Government Infrastructure Backlog: The Case for a National Bond Bank, in P. van den Hoek (ed.), *A Global Economy*, Forum for Economists International, Amsterdam, pp. 116-130.

Dollery, B. E., Kortt, M. and Grant, B. (2012), Harnessing Private Funds to Alleviate the Australian Local Government Infrastructure Backlog, *Economic Papers*, Vol. 31, No. 1, pp. 114–122.

Dollery, B. E., Kortt, M. and Grant, B. (2013), *Funding the Future,* Federation Press, Sydney.

Dollery, B. E. and Mounter, S. (2010), Local Government Investment, Maintenance and Renewal: A Comparative Analysis of Contemporary Australian and New Zealand Local

Government, *Australasian Journal of Regional Studies*, Vol. 16, No. 2, pp. 217-232.

Ernst and Young (2012), *Strong Foundations for Sustainable Local Infrastructure: Connecting Communities, Projects, Finance and Funds*, Commonwealth Department of Regional Australia, Local Government the Arts and Sport, Canberra.

House of Representatives Standing Committee on Economics, Finance and Public Administration ('Hawker Report') (2004), Rates and Taxes, Government of Australia, Canberra.

Local Government Association of Queensland (LGAQ) (2006), Size, Shape and Sustainability, LGAQ, Brisbane.

Local Government Association of Tasmania (LGAT) (2007), Review of the Financial Sustainability of Local Government in Tasmania, LGAT, Hobart.
NSW Independent Inquiry into Local Government (LGI) ('Allan Report') (2006), Are Councils Sustainable?, LGI, Sydney.

Municipal Association of Victoria (MAV). 2005. Trends in Local Government Finance, Melbourne: Municipal Association of Victoria.

NSW Independent Pricing and Regulatory Tribunal (IPART) (2009), Review of the Revenue Framework for Local Government, NSW Government, Sydney.

PriceWaterhouseCooper (PWC) (2006), *National Financial Sustainability Study of Local Government*, PWC, Sydney.

Productivity Commission's (PC) (2008), *Assessing Local Government Revenue Raising Capacity*, PC, Canberra.

Scharfstein, R. & Stein, J., 1990, Herd behavior and investment, American Economic Review, Vol. 80, pp. 465-479.

Simmons, P.R. and Cacho, O.J., (2005), A possible conflict between economic efficiency and political pressure, Journal of Computational Economics, Vol. 26, No. 2, pp. 129-40.

Simmons, P.R. & B. Dollery, (2014), Explaining the Australian Local Government Infrastructure Expenditure Backlog: A Market Failure Approach, Economic Papers, 33(3), 275-284.

South Australian Financial Sustainability Review Board (FSRB) (2005), Rising to the Challenge, FSRB, Adelaide.

Szpiro, G., (1997), The emergence of risk aversion, *Complexity*, Vol. 2, No. 4, 31-9.

von Neumann, J. and Morgenstern, O., (1947), *Theory of games and economic behaviour*, Princeton University Press, Princeton, Ch. 1-4.

Western Australian Local Government Association (WALGA) (2006), *Systemic Sustainability Study*, WALGA, Perth.

TABLE 1: PWC (2006) Australian Local Infrastructure Backlog Estimates

Type of Estimate	**Infrastructure Renewal Backlog ($m)**	**Expenditure Shortfall on Existing Infrastructure Renewal ($m pa)**	**Estimated Infrastructure Funding Gap pa ($m pa)**	**Estimated Infrastructure Funding Gap per Council ($m pa)**
Total NSW/WA/SA/Vic	$9,156	$711	$1,362	$3.1
'Low-case' national estimate	$12,012	$922	$1,826	$2.6
'Mid-case' national estimate	$14,533	$1,129	$2,163	$3.1
'High-case' national estimate	$15,305	$1,190	$2,281	$3.3

Source: Adapted from Dollery and Mounter (2010), Table 1.

TABLE 2: PWC (2006) Australian Local Infrastructure Backlog Estimates Per Capita

Type of Estimate	Infrastructure Renewal Backlog	Expenditure Shortfall on Existing Infrastructure Renewal pa	Estimated Infrastructure Funding pa
'Low-case' national estimate	$571	$44	$87
'Mid-case' national estimate	$692	$54	$103
'High-case' national estimate	$728	$57	$109

Source: Adapted from Dollery & Mounter (2010), Table 2.

Table 3: Values of p in Initial Period and after 60 Periods for a Typical Run

Period	p values across the 20 councilors
1	0.9844, 0.6595, 0.7088, 0.8886, 0.1553, 0.5328, 0.9756, 0.9395, 0.8673, 0.175, 0.2841, 0.07257, 0.2641, 0.1903, 0.2303, 0.5585, 0.7782, 0.02419, 0.3629, 0.4143
60	0.5113, 0.5113, 0.5113, 0.5113, 0.5112, 0.5112, 0.5112, 0.5112, 0.5112, 0.5112, 0.5112, 0.5112, 0.5112, 0.5112, 0.5112, 0.5112, 0.5112, 0.5112, 0.5112, 0.5112

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Figure 1: Results for values of p over 60 generations