Australian Government

Department of Infrastructure, Regional Development and Cities

Bureau of Infrastructure, Transport and Regional Economics

Economies of scale and regional services

At a glance:

- This paper examines how economies of scale influence the geographic distribution of services in Australia's regions.
- Economies of scale are situations where it is on average cheaper per unit to produce more of a good or service than it would be to produce less. In other words, economies of scale exist when average cost falls as the quantity of goods or services produced increases.
- Economies of scale are common in service provision for a number of reasons, the most common of which is that there are indivisible inputs. Examples include rent and other accommodation costs, utilities, specialised equipment and minimum levels of staffing that need to be paid for no matter how many services are provided.
- Due to economies of scale there is minimum level of demand needed for a service to be viable. A doctor's practice provides a simple example: there are fixed costs regardless of the number of patients. For the practice to be viable there will need to be enough patients to cover these fixed costs. As demand for services is highly related to the local population, economies of scale mean low populations may be unable to support a local service provider.
- Local economies of scale reduce the average cost when more is produced from a certain place, which could be an entire country, a town, or often, a location like a school or a hospital. These shape the distribution of services in regional Australia by providing an incentive to centralise service provision into locations where there is higher demand for services.
- In regional service provision, competing forces lead to a tension between the benefits from economies of scale and transport costs. Greater economies of scale increase the incentive to centralise service provision into fewer, larger locations, while increased transport costs increase the incentive to decentralise service provision into more, smaller locations.
- Primary and secondary schools provide an example of this tension in practice. Secondary schools have greater economies of scale than do primary schools, resulting in greater centralisation of secondary school services relative to primary school services.

Introduction

In this paper, we set out to describe the consequences economies of scale on where services are produced. Economies of scale describe any situation where on average it is cheaper per unit to produce more of a good than it would be to produce less. This is a very general idea, not linked to what is being produced, who produces it, where production is taking place or how much is produced. It describes any situation where the total cost per unit, otherwise known as the average cost, falls as production increases.

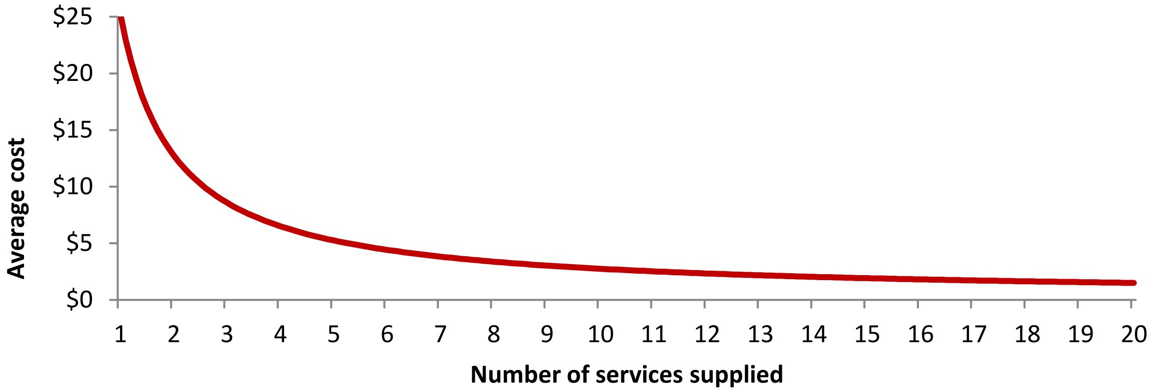
This paper is split into two sections. The first describes how economies of scale arise, and outlines their spatial consequence. This section first addresses the way that local economies of scale create an incentive to centralise production, then the effect of economies of scale on the population required to sustain a service provider. This second section provides an example of economies of scale using a short case study on the differences between school based primary and secondary education. This provides a practical example of the increased centralisation and increased population required to sustain a service caused by increased economies of scale. Before entering into these sections, the remainder of this introduction provides an overview of economies of scale and provides some key definitions.

Historically, economies of scale have dominated thinking about where goods and services are produced. Although they only offer a partial explanation, they remain a fundamental force shaping the geographic distribution of economic activity. They help explain the existence of many of the spatial concepts we often take for granted. Places like cities and towns or geographic divisions like metropolitan, regional, urban or rural are at least in part generated because of the pervasive existence of economies of scale.

Economies of scale are ubiquitous in service provision, at least at low levels of production. The most common reason are the existence of indivisible inputs. Examples include rent and other accommodation costs, utilities, specialised equipment and minimum levels of staffing, that need to be paid for regardless of how many services are provided. Other often cited reasons include learning or developing how to provide the service at the same time as the service is produced, knowledge spill-overs and the nature of some kinds of production processes. A discussion of how and why economies of scale arise can be found in Appendix A.

The average cost curve associated with economies of scale has a very specific shape: it must fall as more services are supplied. This is shown below in Figure 1, which illustrates a very simple example of a cost curve that reflects economies of scale caused by there being some indivisible input or inputs in the production of the service.

Figure 1: A simple average cost curve reflecting economies of scale



Source: BITRE analysis

There are spatial consequences to economies of scale wherever the effects are local rather than global. Examples of *local economies of scale* include situations where the total cost per unit of production falls at a factory or in a service centre, or where it falls close to where production is taking place, for example a central business district, a town, city, or even a country. The common feature is that there is some geographic limit to where the economies of scale can be realised. *Global economies of scale* have no geographic limit. The increased production by any producer reduces overall per unit costs for all producers in the entire economy. Because these economies of scale have no geographic limits they have no specifically spatial impact on where services are produced.

Local economies of scale are an incentive to produce services in the location in which economies of scale exist. In other words, they provide an incentive to centralise production. As well as the benefits of taking advantage of economies of scale, centralisation also involves costs to both producers and consumers. Centralisation means that the service is further away from some consumers, who have increased transport costs for the service. These include the upfront cost of travel, like a bus ticket or fuel, the opportunity cost of the time spent traveling, and any psychic costs like the discomfort of longer journeys. This reduces the benefit consumers get from a service and in turn reduces demand for the service. There are also direct costs to the producer that include all the normal costs of locating in a given spot – the transport costs of inputs, the cost of land, etc. The costs and benefits of centralisation are weighed by public and private decision makers in choosing the location from which to provide services.

A further useful distinction can be made between internal and external economies of scale. *Internal economies of scale* are situations where the benefits are only realised by the entity that produces the goods or services. *External economies of scale* are situations where the benefits are realised by parties other than (or as well as) the entity that produces the goods or services, for example where there are reductions in the average cost to other producers in the same town, industry or even economy.[1]

[1] This is a generalisation of Marshall's classifications in Marshall 1920.

The geographic impact of economies of scale

Economies of scale are a centralising force if the benefits of increased production are localised in space. This is because there is an incentive to increase production at a location where the total cost per unit produced falls as more is produced at that location.

Centralisation, however, comes at a cost in terms of consumers' access to a service. The extent to which a service should be centralised into a single geographic location is a trade-off between centralising forces like economies of scale and the improved access that can be achieved by having more geographically distributed service provision. The best solution chooses a degree of geographic centralisation that balances these costs and benefits. The components of this trade-off are considered in more detail in the discussion below.

Economies of scale and centralisation

Where economies of scale have a local effect they are a fundamentally centralising force because they provide an incentive to centralise economic activity – in this case production – in space. The incentive is a reduction in the total cost per unit as more is produced in a given location. Like all location decisions centralisation will occur until the benefits of centralising are equal to the costs of centralising (for the decision maker). This means that so long as the costs of centralising remain the same, the greater are the returns to scale, the more centralised production will be.

Economies of scale are related to the centralisation of economic activity because they influence the efficient number of locations from which a service is produced, or service points, for a given cost structure. Fewer service points take advantage of economies of scale as each point serves more consumers. Having many service points (that each service only few consumers) loses these advantages. The trade-off revolves around the benefits from centralising production, namely taking advantage of the economies of scale, on the one hand, and the benefits of decentralisation, namely reducing the cost of accessing the service, broadly described as access costs, on the other.

Access costs are a very broad category of costs that span everything that a consumer has to pay, forgo, or would pay to forgo, to access a service. These are related to every dimension of access, however, in this paper the definition is restricted to costs that have a relationship with space. This is because the particular focus of this investigation is on the relationship between service access and geography. A more in depth discussion of the dimensions of access can be found in the BITRE staff paper *What is Access?* (Reoch & Thomson 2019).

For the purposes of this paper *transport* costs refer to every type of access cost to the consumer related to moving from one location to another to access a service. This includes the monetary costs of transport (bus tickets, fuel, etc.), the opportunity cost of time (i.e. missed work or paying a babysitter), and the effort of travelling.

Greater economies of scale increase the incentive to centralise production, while increased transport costs increase the incentive to decentralise production. This trade-off defines the number of service providers and their locations, both for centrally planned services (like many government and not-for-profit providers) and private providers in markets. The following section briefly outlines the intuition and mechanics of this situation, while a more technical explanation can be found in Box 1 below.

The case of economies of scale is different from the standard case in economics where a producer sets the price equal to the marginal cost (the most efficient outcome), because this would cause the producer to make a loss. Assuming that a producer is self-sustaining, for them to survive they need revenue that covers their costs, so on average the revenue must be greater than the average cost. By definition, where there are economies of scale the cost of producing an additional unit (marginal cost) is below the average cost. A firm that set marginal cost equal to the price they receive per unit would go out of business. In this situation the question is not so much of achieving the perfectly efficient solution (marginal cost equal to marginal benefit), as achieving the most efficient solution possible (average cost equal to marginal benefit). Because there are returns to scale the discussion in Box 1 concentrates on the most efficient possible trade-off between centralisation and decentralisation, given that the producers are self-sustaining.

A planner with perfect information would have a simple decision: if the benefits of the economy of scale outweigh the transport and other costs, then centralise provision, otherwise, decentralise. The point between these extremes is where the average cost of production plus the transport costs are equal to the what the consumer is willing to pay, in terms of money, opportunity and the other things a consumer suffers or gives up to access a service (their *willingness to pay*). This represents the most efficient possible outcome for a self-sustaining producer, given the constraints.

The market solution is surprisingly similar if firms can freely enter the market. This is also explored more formally in Box 1, however the intuition is that if producers can freely enter they will do so until the last potential entrant can no longer make a profit. As discussed above, the point of zero profit is where the average cost is equal to the average revenue, which in this case is the price received by the firm. Consumers who have to pay transport costs effectively deduct them from what they are willing to pay for the service, so that in total they pay the cost of the service, plus the access costs. Again, the average cost of production plus the transport costs are equal to the willingness to pay of the consumer, which again is the most efficient outcome. An interesting side observation is that it does not matter who pays the transport costs, they will always be passed on to the consumer if the producer is following average cost pricing.

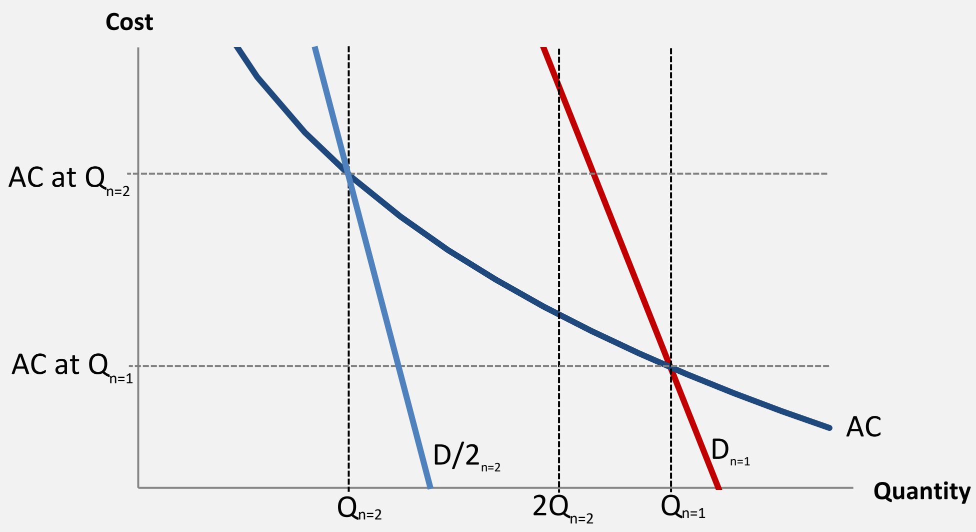
A few simple mechanics govern this relationship. First, decreases in the cost of transport reduce the benefits of decentralisation and increase the relative benefits of centralisation (caused by economies of scale). And second, increases in economies of scale, which can be caused by increases in the fixed cost of production, tend to increase the centralisation of services into fewer service points. These two forces govern the extent of centralisation in a service.

Box 1: Economies of scale and centralisation

This box provides a more formal illustration of the trade-off between the benefits from economies of scale on the one hand and the transport costs of centralisation on the other for an internal economy of scale. Figure 2 (below) shows the difference between having one firm or having two firms in a market where there are economies of scale. All firms have the same cost structure and so have the same average cost curve, labelled *AC* in the figure. The average cost curve exhibits economies of scale as it decreases as more is produced. This means that it is not possible for firms to survive by producing where price is equal to the marginal cost (standard case), in which case the most efficient (unsubsidised) alternative is to produce where price is equal to the average cost.

There are two demand curves shown, the right most demand curve, $D_{n=1}$ represents the demand that a single producer faces in the market when there is only one producer. The left most demand curve $D/2_{n=2}$ *is* exactly half of $D_{n=1}$, and represents the demand curve faced by each of the two producers when there are two producers in the shared market.

Figure 2: Benefits of centralisation



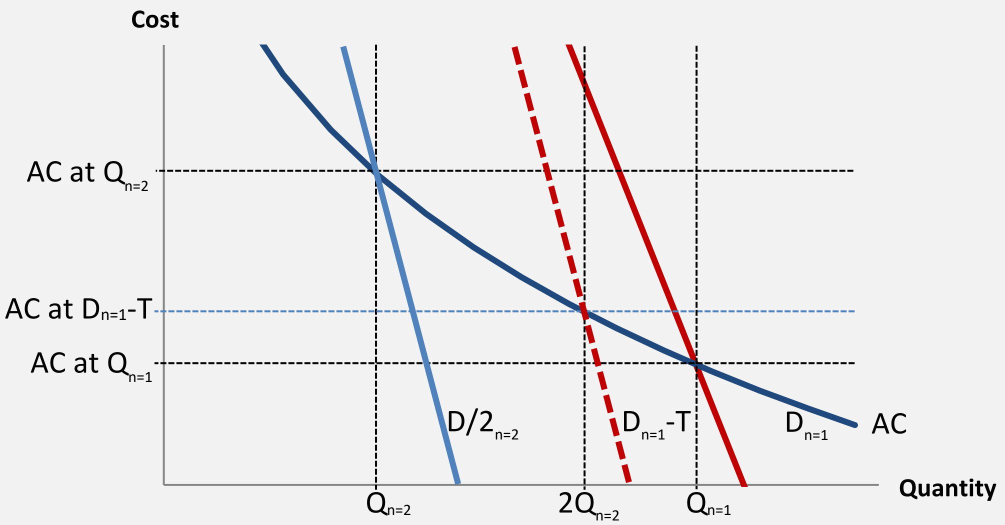
If there were two producers in the market the minimum each producer could charge/receive in revenue is the point where the price (marginal benefit) is equal to the average cost – in other words where demand and the average cost curve intersect. The average cost at this level of production is shown by the horizontal line *AC at* $Q_{n=2}$ and the quantity produced by each firm is shown by the vertical line $Q_{n=2}$. As there are two identical producers the total production in the market is exactly double that of one firm, and is shown by the vertical line $2Q_{n=2}$. Although together the two firms produce double the quantity, the fact that they are separate firms means that they do not fully take advantage of the economies of scale. For this reason, although the quantity is doubled the average cost remains at *AC at* $Q_{n=2}$.

Due to the economy of scale a single producer has an advantage and they would be able to produce more for a lower average cost. The average cost of a single producer is shown by the horizontal line *AC at* $Q_{n=1}$ and the quantity is shown by the vertical line $Q_{n=1}$.

Whether or not it is better to have one or two services depends on the costs and benefits of each option. On the one hand, one service is able to take advantage of economies of scale. On the other, two services can reduce the transport costs of accessing the services. The simplest example is that of two producers in different locations, meaning that two producers reduce the transport costs paid by consumers. Equally, the producers may be different in other ways, for example having slightly different operating hours, different customer service offerings, or other factors which better meet the preferences of some users. The loss of the benefits that arise from having two producers can be represented as a cost when there is only one producer. This ‘transport cost’ (or T for short) of one producer is traded off against the benefits of returns to scale that come from having one producer.

The transport costs (T) mean that there is an advantage in having two producers, as these costs are avoided. Where the benefits from returns to scale are greater than the transport costs it is better to have one service. On the other hand, if the transport costs outweigh the benefits from returns to scale, it is better to have two services. Figure 3 shows the point at which the transport cost is exactly high enough that the output of one producer would be the same as the combined output of two producers (*2Qn=2*). Which is the better option depends on a comparison of the consumer surplus, production costs and transport costs in each case.

Figure 3: Balancing the benefits of centralisation and transport costs



This is a detailed explanation of a fairly intuitive concept: there are benefits to centralisation, of which economies of scale are one of the most important, and benefits to decentralisation, as it improves access by reducing the transport costs to consumers and can increase consumption. The best solution depends on the costs and benefits of this trade-off.

Economies of scale in government schools

This second section of the paper illustrates the geographic effects of returns to scale. This uses the example of school based education, and begins by showing first that there are economies of scale to schools, and then that the magnitude of the economy of scale is different in primary and secondary schools. We then show how this corresponds to differences in their respective geographic distribution and to how this relates back to our comparable measures of access.

Education is not uniform across school levels and depends to some extent on the abilities of the child and becomes more complex as a student ages. The division between primary and secondary education rests on this transition, with primary schools providing more simple content and requiring few specialist facilities or resources. The most important resources, the teachers, are usually generalists who teach (almost) all subjects to one group of students. In contrast secondary education has more complex content and requires some specialist facilities and resources, especially with respect to teachers, who are more specialised and teach multiple groups of students a specific subject.

In addition to the classification of services into primary and secondary level, there are 435 special schools that only provide education services to students with special needs. These include schools that provide services to students who have mental or physical disability or impairment, slow learning ability, social or emotional problems, or are in custody, on remand or in hospital (ABS 2014a). While students in these schools are also often described as being in either primary or secondary level education, due to the highly specialised nature of the services provided, these are considered a separate level of education services for the purpose of this paper.

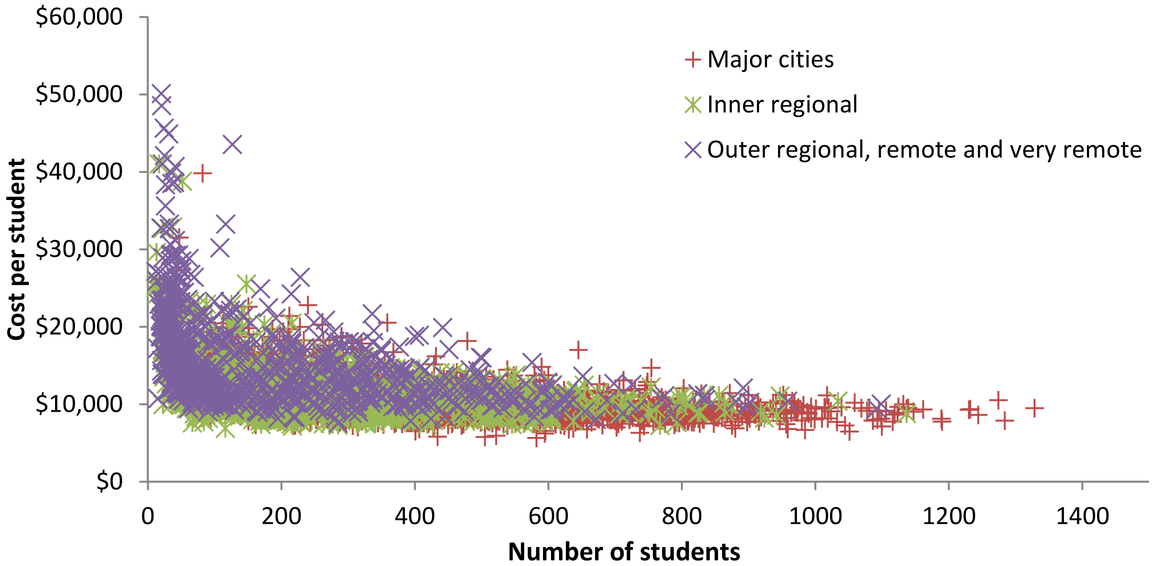
These differences directly translate into differences in cost structure. First, if we consider indivisible inputs, we can see that specialist facilities (science or computer laboratories for example) are large and indivisible inputs because having resources for one class for a few hours a week is the same as for many classes for a few hours a week. Specialist labour is also another important partially indivisible input in education, as is the curriculum, if developed by the school, and the lesson plans of teachers. Because of the greater complexity in secondary education, however, there are more indivisible inputs than in primary education.

Empirically we do see that there are economies of scale in both primary and secondary level government schools when we look at total school funding.[2] This is based on the assumption, which we will use throughout the remainder of this paper, that government schools spend their funding to maximise the education of their students. This assumption implies that yearly total net recurrent funding will be an accurate reflection of actual yearly school costs, and so our analysis will proceed on the basis of using a school's funding to imply a school's cost. Figures 4 and 5 below show the

[2] Because it is not possible (in the data available to BITRE) to accurately assess what proportion of students in a combined school are undertaking primary and secondary education combined schools have been left out of the analysis.

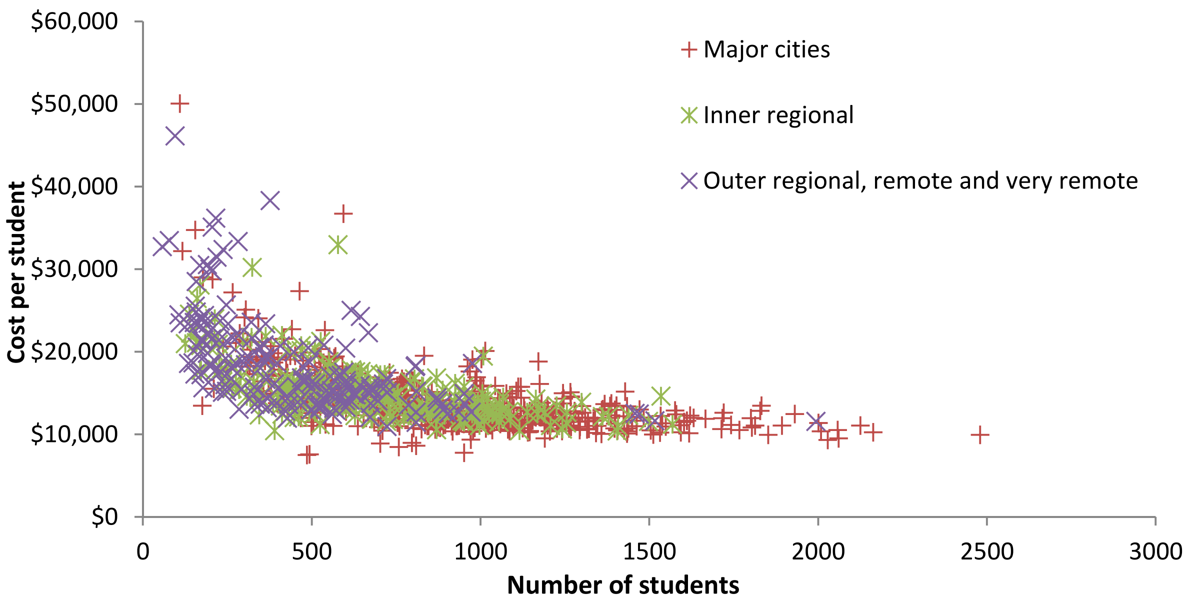
average cost per student of Government Primary and Secondary schools respectively. The economies of scale can be seen in the decreasing relationship between the number of students (horizontal axis) and the cost per student (vertical axis). The similarity between this relationship and the shape of the stylised example of indivisible inputs in Figure 1 (page 3) is striking and supports the idea that there are economies of scale from indivisible inputs.

Figure 4: Government primary schools; average cost per student by number of students ($, 2014)



Source: BITRE analysis of ACARA schools dataset 2014

Figure 5: Government secondary schools; average cost per student by number of students ($, 2014)



Source: BITRE analysis of ACARA schools dataset 2014

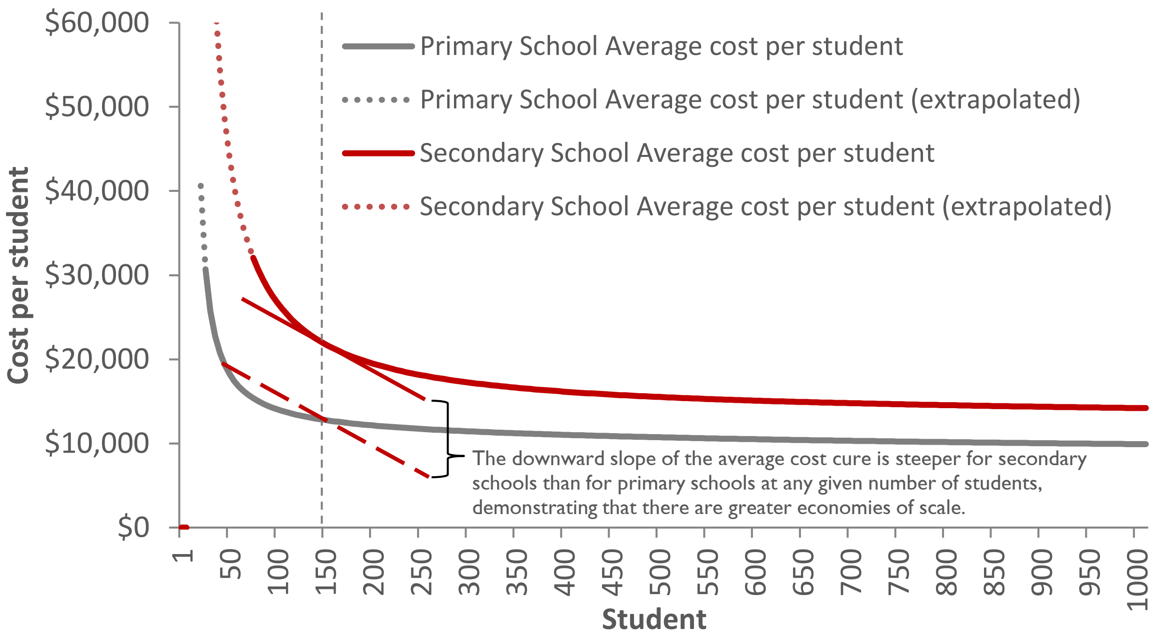
The "curved L" shape (∟) of Figures 4 and 5 display a general pattern where initially average cost per student falls steeply as the number of students increase, but which becomes less steep as the number of students increases. This is a rough pattern because there are many other factors, such as the location of the school and the characteristics of the students, which also affects cost. This creates variation in cost per student which can be seen in the distance between the highest and lowest average costs per student at a given school size, which is especially wide where there are few students and becomes narrower as student numbers increase.

To show this relationship more clearly we have developed a model of school costs for government primary and secondary schools, shown in Figure 6 below. This model is based on 2014 yearly total net recurrent funding and rests on the assumption that this reflects school costs. The objective of the model is to hold all other relevant factors constant and show how school costs vary with student numbers. The model is based on 4,208 Government Primary Schools and 975 Government Secondary Schools with complete information from the 2014 ANCARA schools dataset. It explains around 97% of the variation in the cost of government primary schools and 94% of the variation in the cost of government secondary schools.

A summary of the results of the school cost model are shown below in Figure 6, while a technical description of the model can be found in Appendix B . The results shown below have been averaged across all states and territories and show a primary and a secondary school that:

- has students with an average BITRE estimated socioeconomic status equal to the Australian average
- has students with average NAPLAN results across all domains equal to the Australian average
- is located in Inner regional Australia (ARIA++ of 1)

Figure 6 Economies of scale in government primary and secondary schools



Source: BITRE econometric analysis of ACARA schools dataset 2014

Figure 6 shows that total cost per student falls as the number of students increase, both for primary and secondary schools. This result indicates very strong economies of scale in both primary and secondary schools; however it also indicates that there are greater economies of scale in secondary education relative to primary education.

The shape of the average cost curves in Figure 6 above is also driven by large, indivisible costs, giving it a very similar shape to the stylised example shown above in Figure 1 (page 3). In this example staffing is not specified as a fixed cost. Instead staff have been assumed for simplicity to be perfectly variable, with the teacher to student and other staff to student ratio fixed at the average for each education level. Without this simplification the curves would be 'jerky' as an extra staff member is incrementally added to deal with an increasing number of students.

The model tests the assumption of increasing returns to scale by allowing for a diminishing marginal cost per student at some or all levels of production (using a cubic relationship between students and costs). The marginal cost curve has a statistically significant u-shape for primary schools used in the analysis, but does not for secondary schools (although this does not rule out there being an effect too small to test in the model). Having noted this, the magnitude of increasing returns to scale in primary schools is so small that it is not observable in Figure 6. This is discussed further, along with other technical details of the cost models, in Appendix B.

Geographic distribution of schools

The most important characteristic of school based education in Australia is that all students are entitled to an education of at least a basic standard. This characteristic does not affect all education providers equally, as only the education systems of each State or Territory government (government education) are obliged to provide education to all students. Non-government schools, even where they might like to provide education to all students, are not obliged to do so, and this has a clear impact on their distribution.

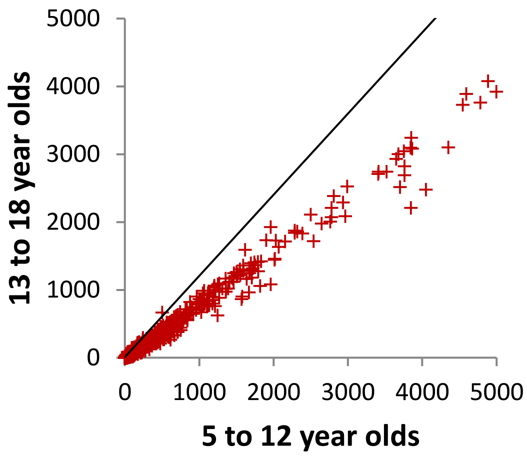
To the extent that education is provided through school, ensuring that all children have access to a basic education is a fundamentally decentralising force. As schools are the primary method of providing education this necessarily means that schools need to be accessible to students. In a very practical sense, schools will need to be physically close enough to the students to commute daily to and from the school to receive at least this minimum level of education. In principle at least, this decentralising tendency should be the same for both primary and secondary levels of education. Children in both age cohorts are both entitled to an education and in general obliged to attend school to the age of 17.

There are consistently more primary school age children than secondary school, because primary school age encompasses either one or two more years than secondary school (depending on the State or Territory). However, as shown in Figure 7 below, the proportion of each age group remains roughly consistent within the vast majority of communities at a ratio of between 5:7 and

6:7,[3] and unsurprisingly both age groups have a very similar geographic distribution across Australia meaning demand for both levels of education is very similar.[4]

Despite how similar demand for primary and secondary education is, in practice the differences in returns to scale mean that we see large differences in their geographic distribution. Because in other respects, such as demand and the cost of transporting students they are similar, the greater returns to scale in secondary education mean that it is more centralised than primary level education.

Figure 7: Primary to secondary aged children in a community



Source: ABS Census of Population and Housing 2011

These differences can be seen in Maps 1 to 4 below, which contrast the distribution of government education by level.

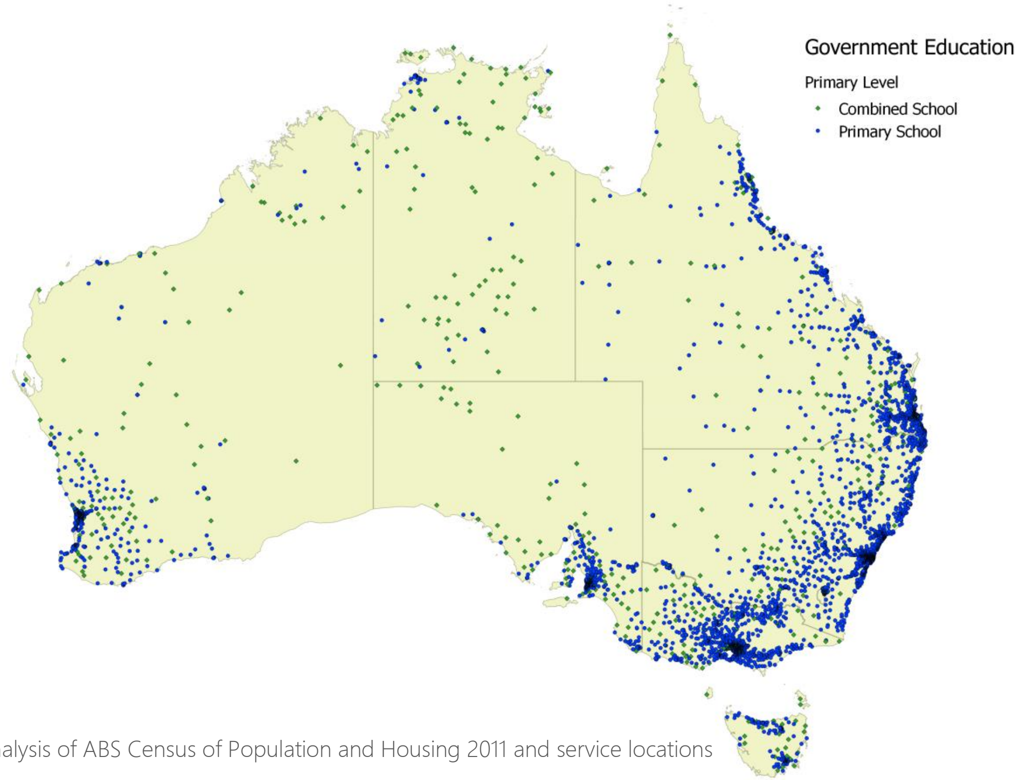
Map 1 shows the location of government primary level education services, constituted by both primary schools (red) and combined schools (green). Map 2 shows the location of government secondary level education services, constituted by both secondary schools (red) and combined schools (green). By contrasting these two maps two important differences stand out. First, there are more primary level education services than secondary level education services. Second, primary level education services are more widely distributed than are secondary level services, which are more concentrated in areas of higher population along the east coast and south west corner of Australia. What secondary level services there are in remote Australia are either located in a major centre or a combined school.

Given the economies of scale in schools it may be surprising that there are so many small schools in Australia. However an important feature of government schools is that they are largely unable to choose the size of the population they service. If there are only a small number of students within accessible distance of a school, then the school will necessarily be small. One way of reducing costs is to take advantage of economies of scope by combining school levels (described in detail in the forthcoming Information Sheet *Economies of scope and regional services)*. Significant inputs can be shared between levels of education, for example infrastructure such as halls, gyms, sports fields, overheads like administrative staff, heating, cooling, etc. Maps 1 and 2 show that combined schools tend to be located in the less populated areas of Australia.

[3] There are some rare exceptions to this relationship, generally in communities which have a boarding school or boarding house catering to secondary school aged students.

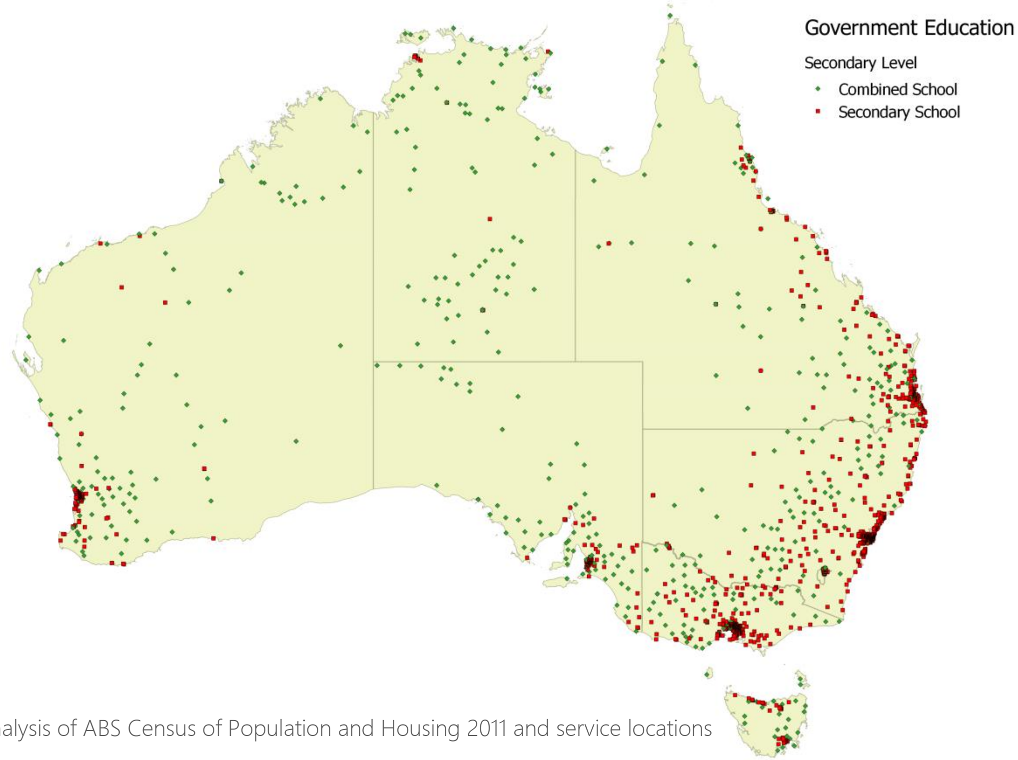
[4] Communities are approximated by Urban Centres and Localities (UCLs). UCLs with more than 5000 children between 5 and 12 years have been excluded in order that the figure has a meaningful resolution. The pattern remains within excluded UCLs.

Map 1: Primary level education services in Australia



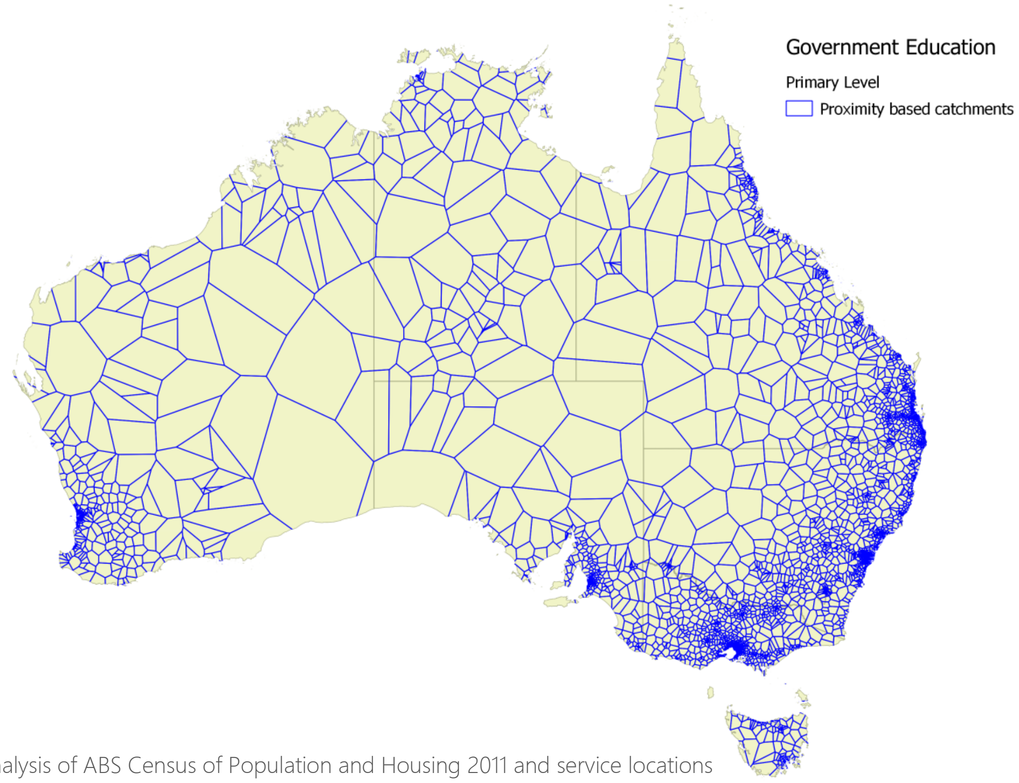
BITRE analysis of ABS Census of Population and Housing 2011 and service locations

Map 2: Secondary level education services in Australia



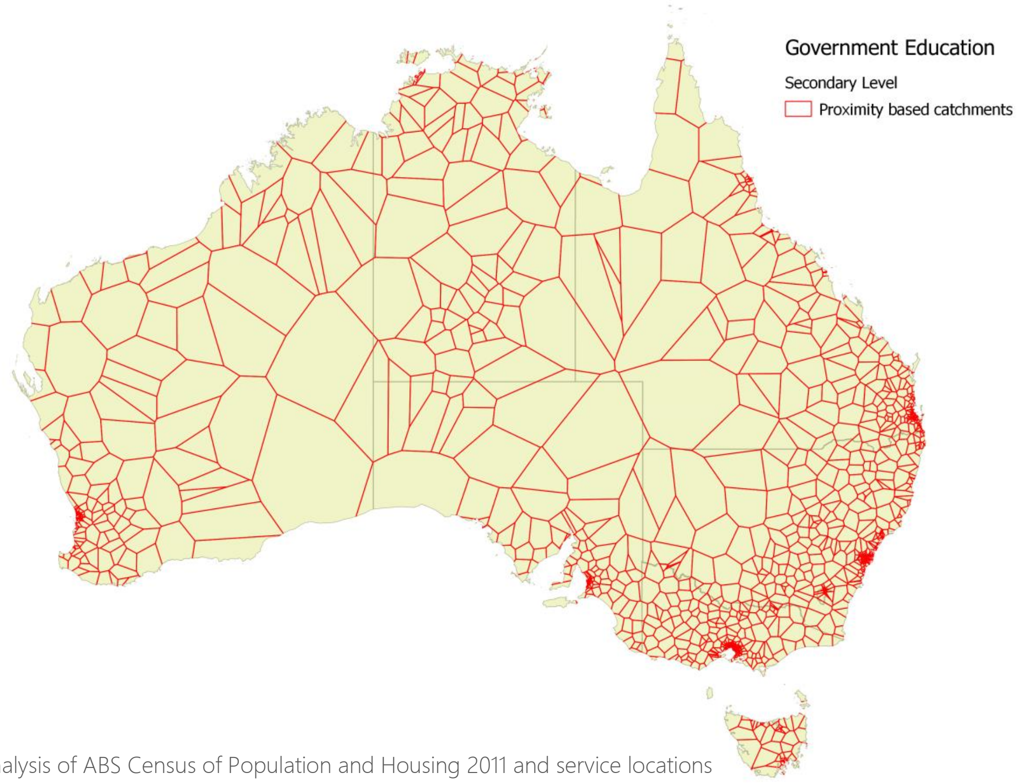
BITRE analysis of ABS Census of Population and Housing 2011 and service locations

Map 3 Primary level estimated proximity based catchment areas



BITRE analysis of ABS Census of Population and Housing 2011 and service locations

Map 4: Secondary level estimated proximity based catchment areas



BITRE analysis of ABS Census of Population and Housing 2011 and service locations

Maps 3 and 4 show the area which is closest to each government education provider. The lines delineate the point at which an area is equally distant from two providers. The polygons enclosed by the lines are the area closest (as the crow flies) to a single education provider located in the polygon (shown in Maps 1 and 2). This is a visual way of demonstrating that the distance between secondary education providers, and thus the area which they service, is larger than it is for primary level providers. This means that many students have to travel further to access secondary education than primary education, a pattern clearest in the more populated south west corner and the east coast of Australia. In the north and centre of Australia this difference is less obvious because both levels of education are predominantly provided through combined schools.

While the full extent of these areas is often very large, sometimes in the hundreds of kilometres, even in the most remote parts of Australia children usually live in settlements where schools are also located. This means that the normal distance students need to travel to a school remains fairly short, even where the maximum area closest to a school is very large.

An alternative way of illustrating the difference in the distribution of the two services is to focus on the students. Figures 8 to 10 below show the estimated distance (as the crow flies) that school aged children or young adults of the relevant age group live from their closest government primary or secondary level education provider, as a proportion of that age group. For primary level education, the estimates are for children aged 5 to 12 years inclusive to a primary or combined school, while for secondary education the estimates are for children and young adults from 13 to 18 years to a secondary or combined school. Estimates are provided for three geographies based on 2011 Remoteness Areas: Major Cities; Inner Regional Australia; and the combined Outer Regional, Remote and Very remote Australia. In order to make a very clear comparison, Figure 11 below shows the estimated proportion of each age group that live less than 5km from a primary or secondary education provider.

Figures 11 to 13 show that students outside major cities on average travel further to access both primary and secondary education. However, although there is this difference in access depending on remoteness, Figure 11 shows that there is a consistent pattern where by user populations are usually further from secondary education than primary education providers, regardless of where they live.

There are some counter intuitive patterns to the distribution of students to schools, as can be seen in Figure 11. Specifically, a larger number of secondary school students live within 5km of secondary level education in Outer Regional, Remote and Very Remote Australia than Inner Regional Australia. This is due to the relatively small geographic size of settlements in Outer Regional, Remote and Very Remote Australia. A student living in a small population centre can often be closer to a school than a student living in a larger population centre. However, on average we estimate that students live closer to a secondary school in Inner regional areas because there are fewer students who live an extreme distance from a school. Table 1 below shows this pattern more clearly. It illustrates that it is common (by mode) for primary and secondary students to live around 1 kilometre from school.

Figure 8: Age cohort distance to provider for primary and secondary education, Major Cities

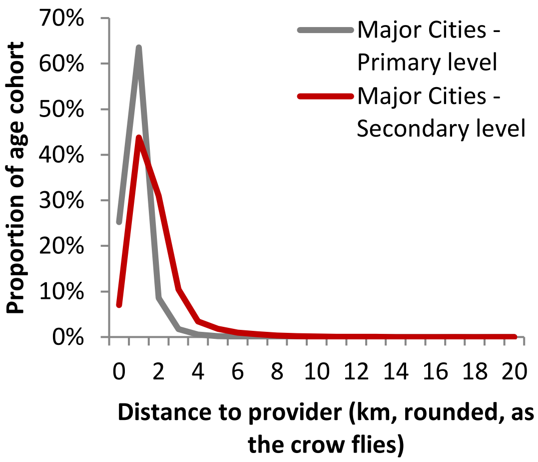
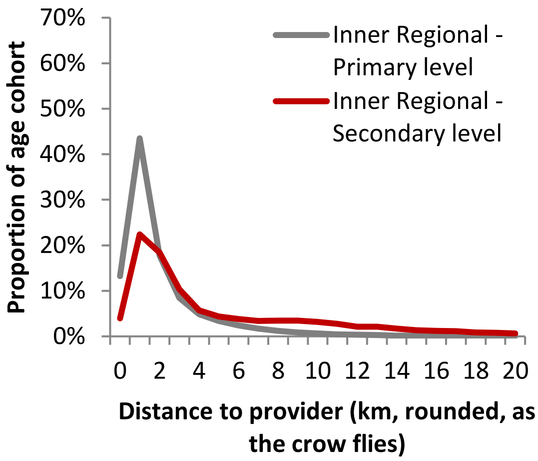


Figure 9: Age cohort distance to provider for primary and secondary education, Inner Regional



Source: BITRE analysis of ABS Census of Population and Housing 2011 at the 1 km grid scale and service locations

Figure 10: Age cohort distance to provider for primary and secondary education, Outer Regional

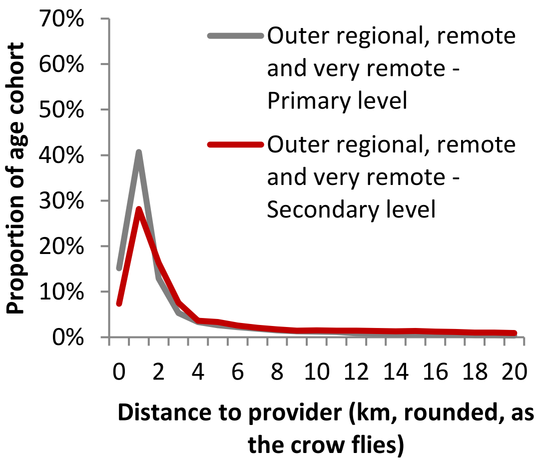
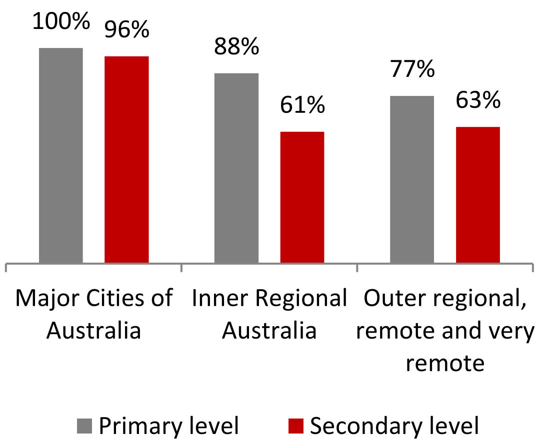


Figure 11: Per cent of age cohort living less than 5km from a primary or secondary education provider



Source: BITRE analysis of ABS Census of Population and Housing 2011 at the 1 km grid scale and service locations

Table 1: Descriptive statistics for distance to service for consumers of primary and secondary education by remoteness area (km, rounded, as the crow flies)

	Primary level Aged 5 to 12			Secondary level Aged 13 to 18		
	Mean	Median	Mode	Mean	Median	Mode
Major Cities of Australia	1	1	1	2	1	1
Inner Regional Australia	2	1	1	5	3	1
Outer Regional Australia	2	1	1	5	2	1
Remote Australia	3	1	1	7	2	1
Very Remote Australia	17	1	1	23	1	1

Source: BITRE analysis of ABS Census of Population and Housing 2011 and service locations

Primary and secondary schools provide an example of economies of scale operating in the provision of a service. The magnitude of the scale is different between the schools, with secondary school having a greater degree of economies of scale. In addition there are spatial consequences to economies of scale, namely, all else being equal, the centralisation of activity. This results in fewer secondary schools (with greater economies of scale) catering to larger numbers of students and more primary schools (smaller economies of scale) each catering to fewer students.

Conclusion

This paper began by describing how economies of scale arise and then outlined the centralising effect that local economies of scale have on service provision. Finally, the last section has provided an example of this effect using primary and secondary education.

Where there are local economies of scale there are benefits to centralisation. Put the other way around, the existence of economies of scale mean that there are costs to decentralised service provision. Balanced against this, there are costs to centralisation, or conversely, benefits to decentralisation, because there are transport costs associated with consuming services and costs to society where people do not consume enough, or any, of a service.

For practitioners and policy makers the most important conclusion to be drawn from this paper is that economies of scale create a tension. Where there are indivisible fixed costs or other factors causing economies of scale, there will be benefits to centralisation. At the same time centralisation generally reduces access because it increases transport costs and reduces the consumption of services. The best decision balances these costs and benefits.

Appendix A: Why do economies of scale exist?

This appendix briefly outlines the causes of economies of scale. Understanding why they arise and when they are likely to be an important consideration is helpful in both understanding the distribution of services and in designing effective service delivery systems. Historically, economies of scale have been so integral to the production of both goods and services that many of the most influential studies have focused on the production of goods, rather than services. This appendix draws from this literature, and some of the examples in this section reflect historical thinking about goods providers. This noted, the insights of each example are as applicable to the production of services.

Internal economies of scale

Internal economies of scale are situations where for a given producer it is on average cheaper per unit to produce more than it is to produce less. In other words, the benefits of scale can only be taken advantage of by the organisation producing the service and not by other producers. These are most commonly related to two aspects of production cost; indivisible inputs and increasing returns to scale, although they can also be caused by other, less common factors.

Indivisibles inputs

Internal economies of scale exist for a variety of reasons. However, the most common is that there are *indivisible inputs*. This means that an input into production has to be bought or consumed in a fixed quantity which is larger than is needed to produce just one unit of a good or service. At least on some scale this is a feature common to the production of almost every good or service. A simple, stylised example of an indivisible input in production is shown in Figure 1 on page 3.

Labour can be an important indivisible input, especially for services which are labour intensive. Take for example a doctor's surgery employing a doctor and a medical receptionist. While the doctor is treating patients the receptionist will be receiving patients, managing appointments and completing other administration. Once the doctor is working full time, more patients can only be seen by employing the hours of an additional doctor. However, with two doctors, the surgery will not need to hire an additional medical receptionist as their front of house work and administration can support the work of both doctors. At this low level of production the costs of the receptionist can be shared among more patients, so that average cost per consultation falls as production increases, resulting in economies of scale.[5] The way that a supervisor can manage a variable number of staff provides another common example of economies of scale in specialist labour. Because services are often labour intensive, the indivisible cost of labour is a particularly important and common source of economies of scale.

[5] See for example Kimbell and Lorant (1977)

Increasing returns to scale

Increasing returns to scale defines situations where increasing the level of inputs more than proportionally increases the level of output. Put another way, as more is produced fewer inputs are required to produce an extra unit. In technical terms we are describing decreasing marginal costs.

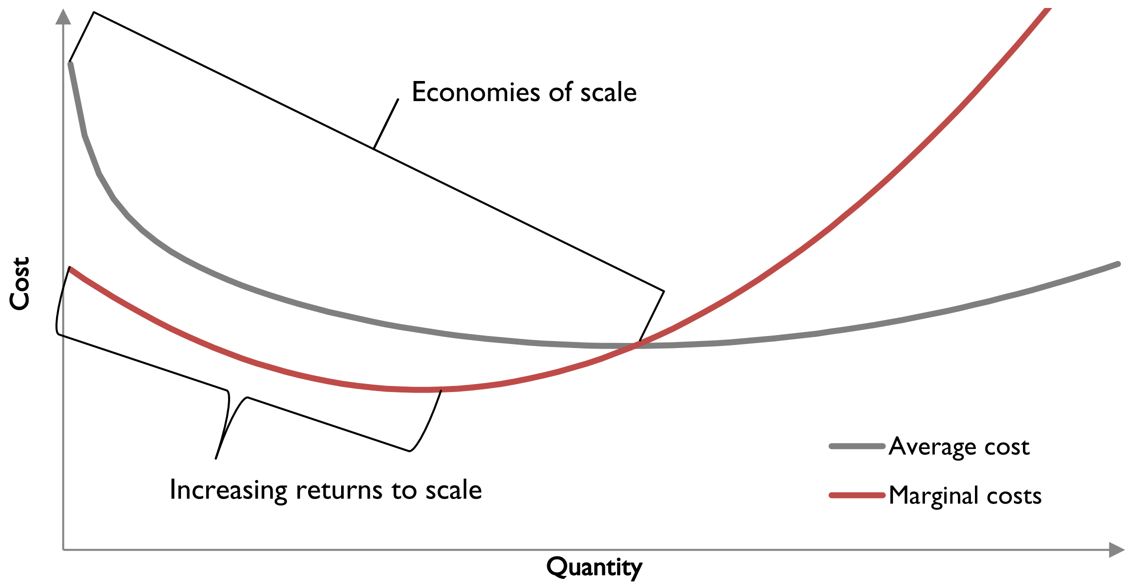
Economies of scale and increasing returns to scale are often confused as they are very closely related concepts. Importantly, where there are increasing returns to scale there will necessarily be economies of scale, however there may be economies of scale without increasing returns to scale.

The difference between economies of scale and increasing returns to scale

Economies of scale refer to a situation where the average cost declines as more is produced, while increasing returns to scale refers to a situation where the marginal cost declines as more is produced. Where there are increasing returns to scale there will necessarily be economies of scale; a declining marginal cost will cause a declining average cost. However the reverse is not necessarily true.

Figure 12 below presents this distinction graphically for the standard neoclassical model where there is a fixed cost of production and a u-shaped marginal cost curve. For a mathematical proof, see Gelles and Mitchel, 1996.

Figure 12: Economies of scale and increasing returns to scale



Source: BITRE analysis

Where increasing returns to scale are observed empirically over time it is sometimes referred to as the learning curve or progress curve, especially in manufacturing. As suggested by the phrase learning curve, a common explanation for a decreasing marginal cost is that people become better at a task with experience – people learn how to produce more as they produce more. This affects other inputs as well and is broadly related to *technology*, or the way in which inputs are used to produce goods and services. Most famously this relationship was observed and measured for airframe manufacture in the United States during the Second World War. In this classic study, the factors found to contribute to the learning curve were: improvement in co-ordination of the inputs; better organisation of the workspace; individual sub tasks carried out more effectively; improved supply system for the inputs; and the development of better tools (Asher 1956). This idea can be applied more broadly to producing any goods or services where the way that production takes place, or the technology, is developed during the production process, so that production becomes more efficient as more is produced.

Factors entirely unrelated to labour (or learning) can also exhibit inherent increasing returns to scale. The most widely cited example is the '2/3 rule' found in chemical manufacturing costs during the middle of the 20th century, which stated that the cost of plant expansion approximately equals the increased capacity to the power of 2/3.[6] Although this rule was not perfectly accurate, it does reflect an underlying feature of the production process, in this case one dominated by containers and pipes of various sorts where volume can be increased with a less than proportional increase in materials (Moore 1959).

While this example may seem very specific to a given industry and a given technology, relationships like the one above can be seen in some common inputs into services. Similar relationships exist in buildings of all shapes and sizes and in many other inputs into producing services. Inherent properties like this 'container principle' can generate increasing returns to scale in services, at least at some levels of production.

Other internal economies of scale

Having market power as a buyer of inputs, or monopsony, can generate economies of scale if increasing production increases the producer's market power. Smaller retailers are less able to negotiate the price of the inputs they purchase and so pay a higher cost per unit. This should not be confused with economies of scale related to high turnover in retail markets, which are generated by dividing indivisible inputs such as rent across a larger volume of sales.

Enterprise size can also reduce the cost of a particularly important input into production – credit. For the smallest enterprise, access to credit is limited to personal contacts, while most enterprises have some access to bank based finance if they have sufficient assets or turnover. This finance is relatively expensive compared with other forms of public finance, such as listing on the stock exchange. However access to public credit such as listing on the stock exchange is restricted, for example on the Australian Securities Exchange to firms with $1 million aggregated profit from continuing operations over the past 3 years and $500,000 consolidated profit from continuing operations over the last 12 months, or $4 million in tangible assets (ASX 2018). The fact that the

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6 This rule reflects the (exponential) relationship between an increase in the area of a sphere (cost of materials) to the corresponding increase in its volume (capacity).

cost of credit falls as an enterprise expands can lead to a falling average cost and so be the cause of economies of scale.

External economies of scale

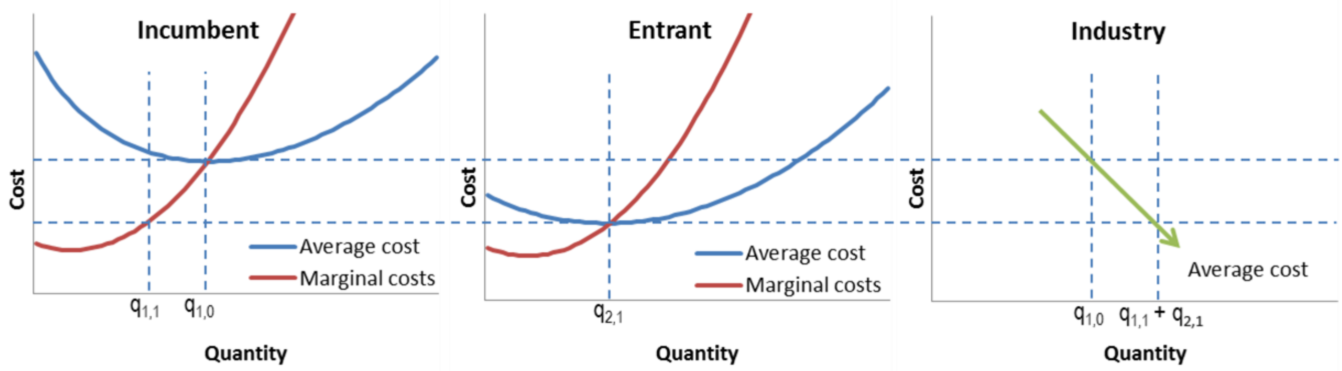
External economies of scale are very similar to internal economies of scale and are generated through the same processes. The key difference is that the benefits are not exclusive to the organisation producing the service and others cannot be excluded from benefiting. A good example are *knowledge spill-overs*, which are caused by a non-excludable indivisible input, specifically, knowledge. A spill-over reduces the cost of knowledge to other producers – so a positive externality is created which reduces the fixed cost of production. This causes the average cost of the industry to fall as production increases overall, but does not cause the average cost of production to decrease for incumbent producer who already paid for the knowledge.

Economies of scale caused by spill-overs

In a spill-over the first producer pays a high fixed cost to enter and create a market. For example, the high fixed cost could be in the development of a new technique (without patent protection). It can also be through the creation of other goods and services, which is not exclusive to the first producer, such as infrastructure or the generation of consumer awareness about the existence of a product.

In Figure 13 below the first panel on the left shows the first firm entering, who becomes the incumbent firm. When they initially enter they will produce somewhere at or above the point labelled $q_{1,0}$. The middle panel shows entrants to the market. They face a lower average cost curve because they do not have to pay some of the fixed cost that was payed for by the first firm. In a competitive environment the entrant firms will produce at the point labelled $q_{2,1}$. With the competition from the entrant firms the incumbent firm will not be able to charge a price that covers the average cost of production. As the fixed cost cannot be recovered, the incumbent will cut production but continue to produce, making an economic loss. This loss relates to their inability to generate a return on the fixed cost that they paid to create the market and which entrant firms do not have to pay.

Figure 13: Stylised relationship between spill over and industry economies of scale



The case of two producers (1 and 2) in two time periods (0 and 1) where producer 2 enters the market in period 1.

Source: BITRE analysis

The final panel shows the net effect of this on the entire market. In total, more will be produced and on average it will cost less, meaning that at an industry level the spill over has caused an economy of scale. It is more efficient for there to be many producers who take advantage of the spill-over than it would be to have only the first firm that created the market. While more efficient (with both consumers and entrant firms benefiting from the expansion of the industry) the incumbent firm is made worse off.

Farming provides an intuitive example of this process as farming technology is difficult to keep exclusive to one producer. New technology, such as improvements in the timing of spraying, fertilising or harvesting or new products can often literally be observed by nearby farmers who are also able to observe the results. Nearby farmers can then apply what they have learnt from their neighbours on their own farms (Läpple and Kelley 2015). This intuition is borne out by studies of the uptake of organic farming, which show that the decision of neighbours to 'go organic' increases the likelihood that neighbour farmers will also 'go organic' (Lewis et al. 2011). As a localised economy of scale (because the information only spills over locally) this causes a centralisation of production at the location where the benefits of scale can be realised, i.e. close to existing organic farms.

Appendix B: Estimating average cost per student

The objective of estimating the cost structure of schools is to assess the extent to which the results show economies of scale. Specifically, the modelling attempts to evaluate an 'average' primary and secondary school in Australia.

The average cost of education per student in primary and secondary schools has been estimated by first estimating an equation for total cost and then dividing this equation by student numbers. This equation is theoretical in that it attempts to estimate total costs using factors which we expect to be important to education. As such no attempt has been made to cull core variables to create a reduced form equation.

Because the costs of a school are not directly observable, yearly total net recurrent income has been used as a proxy for costs. This assumes that each school attempts to maximise the education of its students, within the budget constraint of yearly total net recurrent income and other external constraints such as the background of the students and the isolation of the school. This is largely a short run model as the fixed costs per year are considered but sunk fixed costs – such as the initial construction of buildings and other infrastructure - are not included. However, the costs associated with loans paid directly by the school for capital expenditure are included.

The theoretical model is based on a simple total cost framework:

$$Total\ cost\ =\ Fixed\ cost\ +\ Variable\ cost$$

Where

$$Fixed\ costs\ = Constant +\ f(\ State\ or\ territory\ school\ system)$$

and

$$Variable\ costs\ =\ f\left(\begin{matrix} Number\ of\ students, \\ Number\ of\ staff, \\ Results\ of\ students, \\ Socioeconomic\ status\ of\ students, \\ Remoteness\ of\ school \end{matrix}\right)$$

Number of students

The number of students is measured by the number of full time equivalent students attending the school.

S = Full time equivalent students

Number of staff

The number of staff is broken into two separate variables, representing the number of teachers and the number of other staff employed by the school. Both are measured as full time equivalent.

T = Full time equivalent teachers

O = Full time equivalent other staff

Results of students

Student results are approximated by 2014 NAPLAN Results, and are the average of each of the four domains tested in each year level in a given school. Each domain at each year level is standardized with respect to the scores for that domain at that year level, so that across all schools each domain at a given year level has a mean of 100 and a standard deviation of 10.

R = $\mathit{Results\ in\ a\ school} = \frac{\mathit{Stdz\ Reading} + \mathit{Stdz\ spelling} + \mathit{Stdz\ \ numeracy} + \mathit{Stdz\ persuasive\ writing}}{\sum_{\mathit{Stdz\ Persuasive\ writing}}^{\mathit{Stdz\ Reading}}}$

Socioeconomic status of students

The socio economic status of students is estimated using the BITRE Estimated Socioeconomic Index (BITRE ESI). The BITRE ESI has been developed using the ACARA Index of Socioeconomic Advantage (ICSEA), which itself is derived from a regression analysis of student level factors affecting school results. This has then been adjusted by BITRE to remove the effects of remoteness. The adjustment causes the resulting index to be incomparable to the original index and, as remoteness is an integral part of ICSEA, makes them conceptually distinct. Remoteness is an important factor affecting a student's school performance, however because this is an essentially spatial study it is necessary to separate remoteness from other factors affecting student performance in order to make geographic comparisons. This means that although the BITRE ESI can be compared spatially it is only a partial measure of socioeconomic status (where ICSEA is a more full measure).

The adjustment process subtracts the estimated effect of remoteness from the unstandardized ICSEA score. The estimated effect of remoteness, as approximated by ARIA++, is taken from the coefficient estimates in the development documentation of the ICSEA 2013. As it was not possible to access the exact point ARIA ++ score of a school, the maximum ARIA++ score of the Statistical Area Level 1 (SA1) in which the school is located has been used as a proxy. Adjustments using the minimum and average SA1 ARIA++ score were also tested, however the Maximum score was found to be more significant in the later regression analysis. The adjusted score is re-standardised using the ICSEA mean.

Q = $\mathit{Socioeconomic\ status\ of\ student\ in\ a\ school} = \mathit{BITRE\ Estimated\ Socioeconomic\ Index}$

Remoteness of school

The remoteness of a school (A) is approximated by the minimum ARIA ++ score of the Statistical Area Level 1 in which the school is located.

Model specification:

$Fixed\ Costs\ =\ \boldsymbol{\beta_0} + \boldsymbol{\beta}_{\mathrm{n}}\,\mathrm{D}$

$Variable\ Costs\ =\ \boldsymbol{\beta}_1 S + \boldsymbol{\beta}_2 S^2 + \boldsymbol{\beta}_3 S^3 + \boldsymbol{\beta}_4 T + \boldsymbol{\beta}_5 O + \boldsymbol{\beta}_6 Q \cdot S + \boldsymbol{\beta}_7 R \cdot S + \boldsymbol{\beta}_8 A \cdot S + \boldsymbol{\beta}_9 A \cdot S^2$

Where:

β_0 approximates generic Fixed Costs

D is a vector of dummy variables that allow the fixed costs of running a school to vary depending in which State or Territory school system the school operates.

$S + S^2 + S^3$ is a specification that allows for a 'u-shaped marginal cost curve'.

$A * S \quad + A * S^2$ is a specification that allows remoteness to increase the cost per student, but allows for this additional cost to change depending on the number of students. This is based on the observation that very large remote schools do not suffer the same effects of remoteness as very small remote schools.

All of the explanatory variables used in this model can be expected to have very significant co-linearity and it would not be meaningful to interpret the estimated coefficients of the initial total cost model separately. This can be seen by imagining varying the number of students by a large amount while keeping the number of teachers constant - a scenario entirely outside the scope of the observations.

State dummies

The base case in each of the regressions is a school located in the Australian Capital Territory, New South Wales or South Australia. State dummies have been included for the remaining states and territories. State dummies for the Australian Capital Territory and South Australia were tested (with the base case being New South Wales), however were removed because they were not found to be significant at the 95 per cent confidence level.

Calculating Average costs

Dividing the model by the number of students we can see the average cost per student is:

$$Average\ Cost\ \ per\ student$$
$$= \frac{\boldsymbol{\beta_0} + \boldsymbol{\beta_n D}}{S} + \boldsymbol{\beta_1} + \boldsymbol{\beta_2 S} + \boldsymbol{\beta_3 S^2} + \boldsymbol{\beta_4}\frac{T}{S} + \boldsymbol{\beta_5}\frac{O}{S} + \boldsymbol{\beta_6}\,Q + \boldsymbol{\beta_7}\,R + \boldsymbol{\beta_8}\,A + \boldsymbol{\beta_9}\,A{\cdot}S$$

Transformation to average costs to some extent overcomes the problems of co-linearity and leads to convenient interpretation and use. The variable $\frac{T}{S}$ and $\frac{O}{S}$ represent the teacher to student ratio and the other staff to student ratio respectively. As a ratio they overcome the interpretation problem noted above and in Figure 6 have been held fixed at their respective average for primary and secondary schools. Similarly, Q and R can be interpreted as the average of a given school, and in Figure 6 are held constant at the respective averages for primary and secondary schools. These averages and simple descriptive statistics for all variables can be found in Table 2 and Table 3 below.

Table 2: Descriptive Statistics: Government Primary Schools, N = 4189

Variable	Mean	Std Dev	Minimum	Maximum
Total Net Recurrent Income (TNRI)	3449767	2179413	161016	13407598
Students (S)	330	235	12	1329
Students squared (S2)	163880	216503	144	1765178
Students cubed (S3)	101902973	205010571	1728	2345215438
Teachers (T)	20.03	13.58	0.00	79.10
Other staff (O)	6.97	5.63	0.00	60.30
Socioeconomic index by Students (Q*S)	335187	248200	11450	1440202
School results index by Students (R*S)	33278	24564	1116	145399
Remoteness index by Students (A*S)	210	489	0	6287
Remoteness index by Students squared(A*S2)	77646	264505	0	4392378
Northern Territory dummy (NT)	0.01	0.10	0	1
Queensland dummy (QLD)	0.18	0.38	0	1
Tasmania dummy (TAS)	0.03	0.17	0	1
Victoria dummy (VIC)	0.24	0.43	0	1
Western Australia dummy (WA)	0.11	0.32	0	1

Table 3: Descriptive Statistics: Government Secondary Schools, N = 972

Variable	Mean	Std Dev	Minimum	Maximum
Total Net Recurrent Income (TNRI)	10605850	4109729	1863835	24679743
Students (S)	779	384	57	2480
Students squared (S2)	855998570	1330199911	185193	15253000000
Students cubed (S3)	754887	730582	3249	6150400
Teachers (T)	60.48	25.51	10.70	162.90
Other staff (O)	18.94	9.11	3.70	57.30
Socioeconomic index by Students (Q*S)	775442	409461	56081	2869360
School results index by Students (R*S)	78012	41292	5324	285589
Remoteness index by Students (A*S)	479.60103	852.28612	0	6107
Remoteness index by Students squared(A*S2)	321969	783788	0	11928108
Northern Territory dummy (NT)	0.01	0.10	0	1
Queensland dummy (QLD)	0.18	0.39	0	1
Tasmania dummy (TAS)	0.03	0.16	0	1
Victoria dummy (VIC)	0.23	0.42	0	1
Western Australia dummy (WA)	0.09	0.28	0	1

Model of Total net recurrent income (TNRI), Government Primary Schools, N = 4189

$$TNRI = \beta_0+\beta_1 S+\beta_2 S^2+\beta_3 S^3+\beta_4 T+\beta_5 O+\beta_6 Q\cdot S+\beta_7 R\cdot S+\beta_8 A\cdot S+\beta_9 A\cdot S^2+\beta_{10} QLD+\beta_{11} VIC+\beta_{12} WA+\beta_{13} TAS+\beta_{14} NT+\varepsilon$$

Model Estimates

Table 4: Analysis of Variance, Primary schools

Source	DF	Sum of Squares	Square	F Value	Pr > F
Model	14	1.93E+16	1.38E+15	9941.15	<.0001
Error	4174	5.79E+14	1.39E+11		
Corrected Total	4188	1.99E+16			

Root MSE	372515	R-Square	0.9709
Dependent Mean	3449767	Adj R-Sq	0.9708
Coeff Var	10.79827		

Durbin-Watson	2.077
1st Order Autocorrelation	-0.039

Table 5: Parameter Estimates, Primary schools

Variable	Parameter Estimate	Std. Error	t-val	Pr>|t|	Tol.	Var. Inf.
Intercept	297169	19557	15.20	<.0001	.	0.00
S	4153.62207	363.98647	11.41	<.0001	0.00	220.61
S2	-1.76261	0.38151	-4.62	<.0001	0.00	205.91
S3	0.00061935	0.00024378	2.54	0.0111	0.01	75.38
T	116019	2491.07464	46.57	<.0001	0.03	34.54
O	46695	2187.98373	21.34	<.0001	0.22	4.57
Q*S	-2.18303	0.45271	-4.82	<.0001	0.00	381.03
R*S	6.43269	4.88366	1.32	0.1878	0.00	434.32
A*S	301.4909	31.40644	9.60	<.0001	0.14	7.13
A*S2	-0.16589	0.05765	-2.88	0.004	0.14	7.02
QLD	-316835	20190	-15.69	<.0001	0.55	1.82
VIC	-621881	15350	-40.51	<.0001	0.77	1.30
WA	324593	24469	13.27	<.0001	0.55	1.83
TAS	-300327	37591	-7.99	<.0001	0.86	1.17
NT	387129	60056	6.45	<.0001	0.86	1.16

Model of Total net recurrent income (TNRI), Government Secondary Schools, N = 972

$$TNRI = \beta_0+\beta_1 S+\beta_2 S^2+\beta_3 S^3+\beta_4 T+\beta_5 O+\beta_6 Q\cdot S+\beta_7 R\cdot S+\beta_8 A\cdot S+\beta_9 A\cdot S^2+\beta_{10} QLD+\beta_{11} VIC+\beta_{12} WA+\beta_{13} TAS+\beta_{14} NT+\varepsilon$$

Table 6: Analysis of Variance, Secondary schools

Source	DF	Sum of Squares	Square	F Value	Pr > F
Model	14	1.55E+16	1.11E+15	1191.21	<.0001
Error	957	8.90E+14	9.30E+11		
Corrected Total	971	1.64E+16			

Root MSE	964381
Dependent Mean	10605850
Coeff Var	9.09291

R-Square	0.9457
Adj R-Sq	0.9449

Durbin-Watson	1.863
1st Order Autocorrelation	0.058

Table 7: Parameter Estimates, Secondary schools

Variable	Parameter Estimate	Std. Error	t-val	Pr>|t|	Tol.	Var. Inf.
Intercept	1244676	201396	6.18	<.0001	.	0.00
S	-1133.22	1039.87	-1.09	0.2761	0.01	166.9
S2	0.33785	0.73137	0.46	0.6442	0.00	298.0
S3	-0.00023	0.00023	-1.01	0.315	0.01	97.26
T	111225	4887.94	22.75	<.0001	0.06	16.23
O	99680	6727.03	14.82	<.0001	0.25	3.92
Q·S	0.90118	1.34918	0.67	0.5043	0.00	318.6
R·S	17.9466	11.8512	1.51	0.1303	0.00	250.0
A·S	278.9813	87.5385	3.19	0.0015	0.17	5.81
A·S2	-0.05693	0.09257	-0.61	0.5387	0.18	5.50
QLD	-1809671	111710	-16.20	<.0001	0.51	1.94
VIC	-1568740	88375	-17.75	<.0001	0.69	1.45
WA	965569	137088	7.04	<.0001	0.65	1.53
TAS	-1479277	204050	-7.25	<.0001	0.85	1.18
NT	740215	326982	2.26	0.0238	0.88	1.14

The explanatory variables explain a significant proportion of the variation in the yearly total net recurrent income in both primary and secondary schools. The adjusted r-squared suggests that the model is able to explain 97% of the variation in primary school total net recurrent income costs and 94% of the variation in secondary schools. This appears very high, perhaps suspiciously so, however it is worth noting that the various school funding models of the Commonwealth and State and Territory governments are based on very similar factors to the model applied here, making this result less surprising.

As suggested above there is very significant co-linearity between explanatory variables, as can be seen in either the low Tolerance or its inverse the Variation inflation shown in Table 4 and Table 5. The result of the co-linearity is twofold. First the variance is inflated, biasing the tests for significance towards not rejecting the null hypothesis that the parameter estimate is equal to zero - in other words suggesting that variables are not significant when in fact they may be. The second is that interpreting the estimated coefficients individually is problematic. This means that caution is needed in interpreting the estimated coefficients or suggesting that they are insignificant.

The regression for secondary schools shows some evidence of 1st order auto correlation, the presence of which cannot be rejected at the 95% level of significance but can be rejected at the 90% level of confidence. This is not surprising in cross sectional data of this type where the error terms may be correlated with each other in terms of social and geographical factors. This may mean that the regression is not the most efficient estimate; however the estimator will still be unbiased. As this is a marginal case no attempt has been made to correct for the presence of autocorrelation.

Within the limitations placed on the models by the factors discussed above, the results do suggest that primary schools have u-shaped marginal cost curves with respect to the number of students, as $S+S^2+S^3$ are significant, the estimate of S^2 is negative and the estimate of S^3 is positive. While statistically significant, the magnitude of this effect is so small as to be negligible. There is no corresponding evidence to suggest that secondary schools have a u-shaped cost curve, but it cannot be ruled out in this framework. On the one hand $S+S^2+S^3$ are not jointly significant (F value: 1.19, Number DF =1, Denominator DF = 957, Pr > F 0.260), on the other this cannot be confirmed due to the co-linearity between other explanatory variables and the potential inefficiency as a consequence of autocorrelation.

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Use of the Coat of Arms

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