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DOES DISTANCE MATTER? THE EFFECT OF GEOGRAPHIC ISOLATION ON PRODUCTIVITY LEVELS

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TABLE OF CONTENTS

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INTRODUCTION

The primary explanation of the differences in material living standards across countries is productivity. Much research effort has therefore been devoted to explaining such differences and trying to identify policy levers that will improve performance. There may, however, be some significant component of the productivity gap with the best performing countries which is not readily amenable to policy. Quantifying such effects is important to better understand countries relative positions and to get a more accurate picture of the differences that are amenable to policy and so avoid unnecessary policy interventions.

This paper examines the capacity for one particular OECD economy, Australia (where geographic disadvantages are significant), to sustain labour productivity growth through convergence with economies with higher labour productivity, such as the United States. Over the past 40 years, Australia's labour productivity relative to that of the United States has been slowly trending up. However, there continues to be a substantial gap in labour productivity levels between Australia and the United State. The persistence of this gap has raised questions about whether other factors might limit the extent to which Australia can catch up to the United States.

One possible explanation for some of the productivity gap might be found in the natural circumstances of the two countries. The United States is a large country (around 15 times larger in population and 18 times larger in output than Australia) and can consequently take advantage of the better potential for economies of scale and scope. Indeed, the 2003-04 Australian Budget Papers highlighted Australia's internal and external geographic circumstance and noted that "fully achieving economies of scale and scope in many industries requires large markets, either domestically or internationally through trade" (Australian Government, 2003). It is readily apparent that these advantages do not reside with Australia.

Gravity trade models have provided a good example of the effect of Australia's distance on one economic measure – trade. These equations have explained how Australia's distance to the world's "economic mass" has an impact on Australia's expected level of trade. In earlier work along these lines, Battersby and Ewing (2005) noted:

"Accounting for the factors [of distance and size] in the gravity trade equation suggests that Australia's comparative trade performance is actually quite strong. These factors, which are ordinarily outside the control of policy, plainly have a role in determining many economic outcomes in a country. In Australia's case, geographic remoteness increases the costs of trading, which in turn lowers the extent of international trade and provides varying degrees of natural protection for Australian industries." (p. 17)

It was suggested that this reinforces the importance of accounting for the "tyranny of distance" (Blainey, 2003) that Australia faces both when comparing Australia internationally and defining appropriate policy solutions for Australia.

Until recently, little evidence had been provided to suggest that any other area of Australia's economic performance is adversely affected by this geographic isolation. However, results from the OECD and the IMF have begun to shed light on the potential effect of geographic isolation on economic performance. Specifically, the OECD (2003) reported that an increase in trade exposure by 10 percentage points of GDP could lead to an increase in steady-state output per capita of around 4%. Research from the IMF (2004) on the economic performance of New Zealand (another geographically isolated country) was also noteworthy because it shed some light on the effect of geographic isolation on economic performance. The IMF (2004) found "strong support for the view that geographic isolation has significantly hampered growth in New Zealand". Their regressions also suggest that Australia's economic growth is hampered by this isolation.

In this paper, a slightly different approach is taken to that of the IMF (2004) and the OECD (2003). Analysis is undertaken at the state level to include the effect of a country's internal geographic proximity on the level of labour productivity. Analysis at the state level reduces (but does not eliminate) the policy and cultural differences that are usually not captured in an international cross-country analysis. The level of productivity rather than the growth rate of productivity is analysed because it is expected that distance acts like a natural protection for the Australian economy. This imposes a condition on convergence with the productivity frontier but does not mean that the rate of growth is any lower than the frontier's in the long run.

To test the proposition that geography matters, a proximity variable is calculated that includes the state's own output and all other economic output in the world weighted by its distance from the state. The indicator that is developed is a combined measure of weighted own-state output, weighted other-state output and weighted other-country output, where the weights depend on the distance to the output.

The results of a cross-section regression of state productivity levels on the factors of production and the proximity variable suggest that around 45% of the productivity gap might be explained by Australia's geographic isolation.

This paper has seven sections. The second section establishes the basis of the hypothesis of this paper by exploring the reasons why geography might matter in terms of labour productivity. This is then followed in the third section with the specification of the model that is used in this analysis. The fourth section then presents an analysis of the data that are used in the empirical application of the model. The fifth section presents the set of results from the estimation of the equations of state labour productivity. The sixth section discusses these results, which suggest that labour productivity is negatively affected by an economy's geographic isolation. Finally, the seventh section concludes the paper and offers some directions for further research arising from this work.

WHY MIGHT DISTANCE MATTER?

The research presented in this paper is based on the premise that over great distances, geographic isolation reduces the labour productivity potential of an economy. The paths through which this effect might come about are varied. In this section, the influences of distance on internal and external economies of scale are presented as the primary channels through which this effect might come about.

Full internal economies of scale arise when unit costs of production for a firm stop falling as output increases. For many small firms, production has to increase only slightly before full internal economies of scale are reached. In these cases, the market for the firm is likely to be only sub-national. This means that a country's population will usually have no effect on a small local firm's ability to profitably reach full internal economies of scale.

For other firms, production can increase substantially before full internal economies of scale are reached. In these cases, operating profitably may require a very large and accessible market, which may not be present domestically. For most countries, there is little reason to expect that this market will be limited to just the local population if the country has a generally open economy. Indeed, large companies that take advantage of internal economies of scale are regularly supported by global markets of suppliers and consumers.

However, transport and trade costs might naturally make an economy more closed and this could create a potential for a national or local scale effect. This could quite well be the case for Australia – a country that is geographically isolated and vast. Indeed, in work that explores this type of effect, Redding and Venables (2002) point out that remote countries have naturally restricted access to markets both for the sale of their product and the acquisition of factors of production and other intermediate goods.

Australia's remoteness from large markets means that firms in some industries are unable to achieve the same economies of scale as those in the same industries in Europe or North America. Reciprocally, the costs of trade for international producers make them less competitive in Australian markets. This higher "world price" in some Australian markets makes domestic firms in related industries profitable without having to achieve the same economies of scale. While this is still an economically efficient outcome, it does means that some Australian firms will be less productive than similar firms based in larger markets.

Australia's internal geography can also limit the ability for some firms to achieve economies of scale. Australia is both sparsely populated and very large. This makes the servicing of population centres in Australia relatively costly as firms either face higher transport costs or establish distribution points that service relatively small populations (or both). The higher costs of servicing the dispersed and small Australian population means that some firms in Australia may be much less productive than similar firms in more densely populated markets.

Redding and Venables (2002) also note that it is becoming clearer that the proximity to centres of technology matter for economic growth. This is directly connected with the economics of agglomeration, which was first explored by Marshall (1920). Marshall suggested that the concentration of economic activity enhanced productivity through the pooling of labour, knowledge and technological spillovers, and input sharing. More recently, research has estimated the effect of density on state and city levels of productivity. For instance, Ciccone and Hall (1996) found that the intensity of labour, human and physical capital of a state had a positive and significant effect on labour productivity. Rosenthal and Strange (2003) have also explored the effect of density on different industries in US cities. They found that spatial concentration produces a number of agglomeration externalities and that these differ across industries. Other similar types of empirical research on the role regional concentration in output and productivity can be found in Ciccone (2002) and Rice and Venables (2004).

This agglomeration allows firms to take advantage of external economies of scale to reduce unit costs in production through spillovers in innovation from other firms and commonality in production and distribution processes with other firms. However, firms in countries like Australia, which are both geographically isolated and sparsely populated, may be less able to take advantage of these external economies of scale simply because it is more costly to establish networks over the great distances both within the country and to other countries.

The hypothesis that geography matters is therefore underpinned by a microeconomic reference to the additional costs of participating in the Australian market and the effect these costs have on any firm's ability to operate profitably in Australia. In the next section, aggregate labour productivity is examined in a standard model to identify whether this microeconomic hypothesis is borne out in the aggregate data.

MODEL SPECIFICATION

A simple specification based on the Cobb-Douglas production function is used to estimate the level of labour productivity by state. This specification allows a comparison with other similar regression results and is relatively easy to estimate. The basic specification of the model without regional effects is presented in equation (1).

$$Y_i = K_i^{\beta_1} L_i^{1-\beta_1-\beta_2} H_i^{\beta_2} \quad [1]$$

In equation (1), Y_i represents the gross output of state *i*, K is an indicator of the capital stock, L is an indicator of the stock of labour, H is an indicator of the stock of human capital and β' are coefficients on these variables. Dividing this equation through by the labour stock and taking logs, equation (2) presents a simple labour productivity model that considers the two capital-to-labour ratios.

$$\log \frac{Y_i}{L_i} = \beta_1 \log \frac{K_i}{L_i} + \beta_2 \log \frac{H_i}{L_i} \quad [2]$$

Additional variables, such as indicators of market concentration and country specific dummies, can then be added to this specification. Equation (3) presents the final specification of the function, with betas identifying the coefficients for estimation, ζ_i representing the indicator of the proximity of state *i* to world economic output, and A*us* representing a dummy variable that indicates whether the state is Australian or not.

$$\log \frac{Y_i}{L_i} = \beta_0 + \beta_1 \log \frac{K_i}{L_i} + \beta_2 \log \frac{H_i}{L_i} + \beta_3 \zeta_i + \beta_4 Aus \quad [3]$$

Rather than being an analysis of productivity through time, this analysis is a cross-section analysis over the states of the US and Australia. While this does not challenge the integrity of the basic functional form (productivity levels are still expected to differ because of factor intensities), the goodness of fit is expected to be lower than time-series estimation as there are no lag dependencies.

DATA

There were a number of challenges in the construction of the dataset for this project. For example, constraints on data availability meant that the output, capital and labour indicators for the United States and Australia were constructed from data that exclude the public and agricultural sectors. In addition, capital stock data were not readily available for the individual states of Australia and the United States and had to be calculated from industry averages. In what follows, the data used in this analysis are outlined.[1]

Labour

The most useful labour data for calculating productivity levels and capital to labour ratios are the number of hours worked in an economy. Unlike the more accessible total workers data, hours worked data capture differences in the proclivity for work between different economies.[2] However, there are a number of problems in deriving the total hours worked data for each state of Australia and the United States.

Firstly, while state-level total hours worked data do exist for Australia, there were no state-level total hours worked data for the United States. Nevertheless, total workers data were available at a state level for the United States. These total workers data were also disaggregated to the level of the "super-sector".[3] Finally, applying US national sectoral hours worked per worker data to these state sectoral total workers data provided the basis for calculating the total hours worked in each state.

However, a second problem arose with these data, namely that the US "super-sector" data did not include the farm sector. To keep the productivity and capital intensity measures broadly consistent, the Australian data had to be made consistent with the US data at a sectoral level.

This then led to the third problem, namely that while Australian state hours worked data were disaggregated to a sectoral level, these data did not include the public sector. To make the US data consistent with the Australian data therefore required the removal of the agricultural sector from the Australian data and the removal of the public sector from the US data.

Finally, some scaling of the sectoral hours worked data was also necessary to maintain consistency with other estimates of average hours worked in the economy (such as estimates from the Groningen Growth and Development Centre).[4]

Capital stock and the capital to labour ratios

To calculate state capital stocks, industry capital-to-labour (K/L) ratios were applied to state sectoral labour estimates. While this implicitly assumed constant K/L ratios for industries across states, it did allow an estimate of the state capital stocks to be developed and used in the labour productivity regression.

Capital stock data for each state of the United States were constructed from two digit standard industry classification (SIC) detail as direct aggregates in billions of 1996 dollars. National capital-to-labour ratios were calculated for each of the labour super-sectors used by the US Bureau of Labor Statistics. This required matching the older capital stock SIC codes with the newer North American Industry Classification System (NAICS) codes. The overlap of some of the codes may reduce the integrity of some of the capital to labour ratios.

After converting the capital stock by industry to capital stock by super-sector, a capital to labour ratio was calculated for each of the eleven sectors (Construction; Educational and Health Services; Financial Activities; Information Leisure and Hospitality; Manufacturing; Natural Resources and Mining; Other Services; Professional and Business Services; and Trade).

The capital stock for each state was then calculated by multiplying the national capital to labour ratio for each sector by the employment for each sector in the state. The US state capita-to-labour ratios are presented in Figure 1. As expected, states with high mining intensities (*e.g.* Wyoming) and higher levels of financial activity (*e.g.* New York) tend to have higher capital to labour ratios.

State capital stocks for Australia were calculated using the same method that was used for the US state capital stocks. The 2001 Australian national capital stock in current dollars data were obtained from the Australian National Accounts. For consistency with the US state data, this was adjusted to 2001 purchasing power parity (PPP) US dollars using OECD (2002) 2001 PPPs for GDP. These state capital stock data are presented alongside the US data in Figure 1.[5]

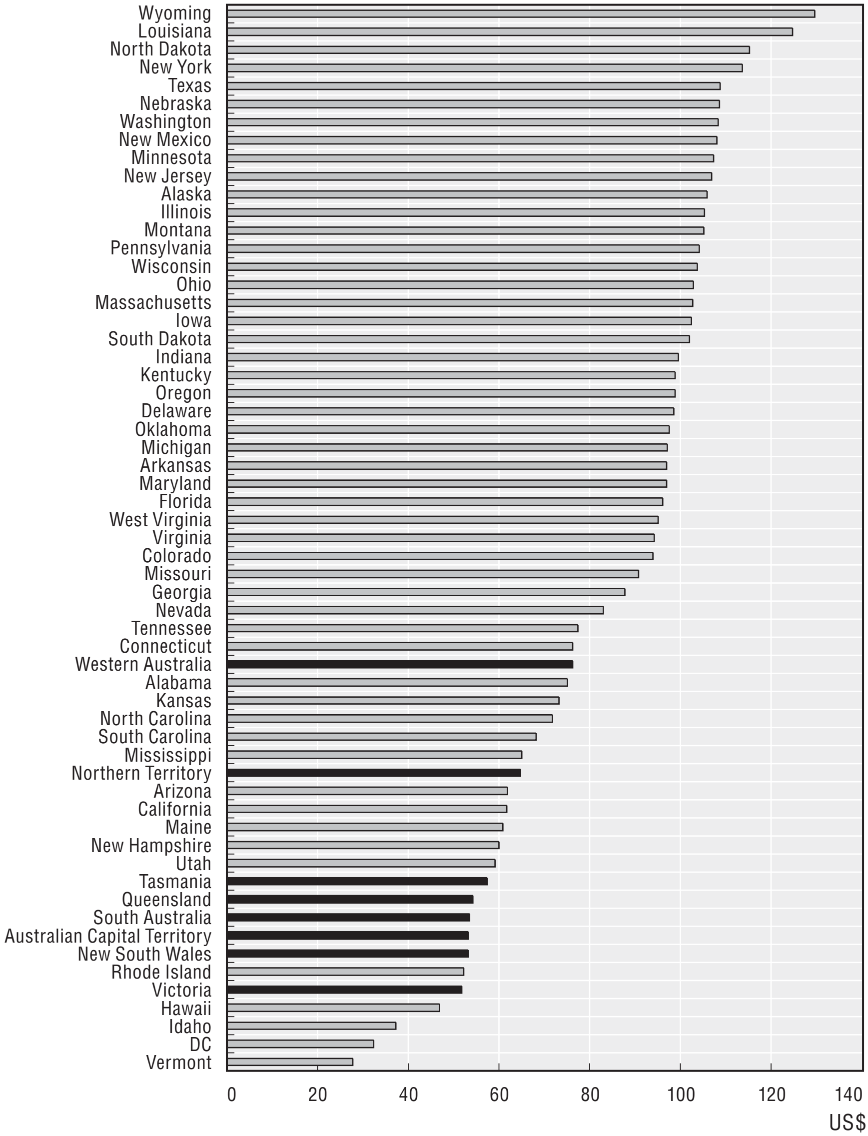
The Australian data consisted of 16 sectors: retail trade; manufacturing; property and business services; health and community services; construction; education; accommodation, cafes and restaurant; agriculture, forestry and fishing; wholesale trade; transport and storage; government administration and defence; personal and other services; finance and insurance; cultural and recreational services; communication services; mining; and electricity, gas and water. The agriculture, forestry and fishing and government administration and defence sectors were excluded from the analysis to retain consistency with the US data.

As with the US data, the Australian states that are particularly mining intensive also had a higher reported capital to labour ratio. However, the capital-to-labour ratios of the Australian states are generally low. Moreover, the Australian states that are particularly mining intensive (Western Australia and Northern Territory) have capital to labour ratios comparable with only a US average.

Given the small workforce of these states and the size of their mining industries, it might have been expected that the capital to labour ratios would be much higher. Indeed, in this analysis, the average capital to labour ratio for Australia is only around 60% of the United States. However, in other work, Schreyer (2005) has estimated that the capital to labour ratio in Australia is around 77% of that for the United States.

A number of biases might explain the lower than expected Australian capital to labour ratios. For instance, the assumption of constant industry capital to labour ratios across states and the possible measurement discrepancies across countries might bias the capital to labour ratios for any of the states. These concerns signal an important caveat and limitation on the interpretation of the results in this analysis.

Figure 1. **Capital per hour worked by state: United States and Australia, 2001**



Source: Bureau of Labor Statistics, *www.bls.gov*, Australian National Accounts (ABS Cat. 5204) and Australian Labour Force Statistics (ABS Cat. 6203).

Output

Gross state product figures for each of the US states were acquired from the Bureau of Economic Analysis. The US gross state products used in this analysis excluded the agricultural and government sectors and were for the year 2001.

Australian state output levels were calculated as the state total factor income less the agricultural and public sectors. These were scaled to distribute the residual between Australian GDP and the total of all state incomes proportionally to each state. This residual was almost solely attributable to the Australian National Accounts item "taxes less subsidies".

These data were then adjusted to 2001 PPP US dollars using the OECD (2002) conversions. Figure 2 presents the resultant output per hour worked for Australian and US states.[6]

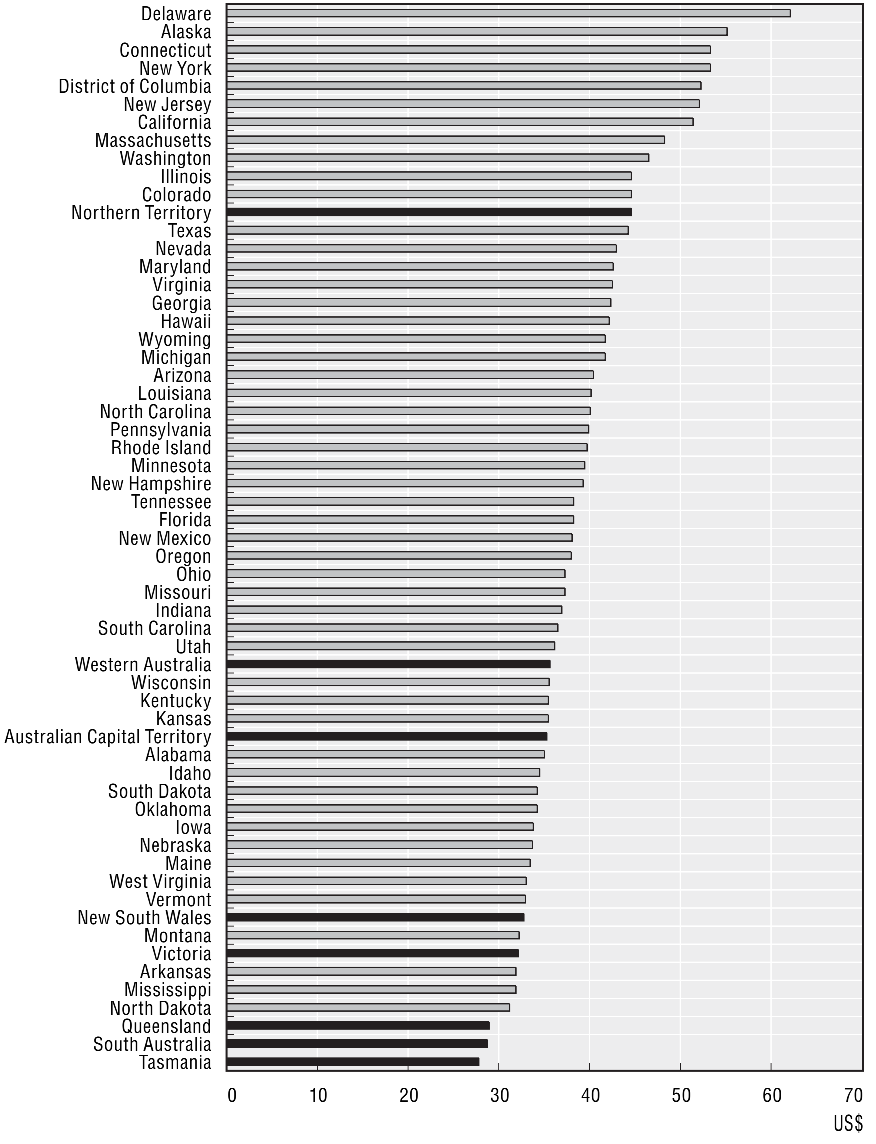
A comparison of Australian and US state labour productivity using these measures suggests that the Australian productivity level is around 75% of the United States. This is around 6 percentage points lower than aggregate economy indicators have previously suggested. For instance, the Groningen Growth and Development Centre (GGDC) data suggest that Australia's productivity was around 81% of that of the US.

As the GGDC data and the data presented here are ultimately sourced from the same locations, the basis for the discrepancy is most likely the exclusion of the agricultural and government sectors. Indeed, the estimate of total Australian non-agricultural private sector GDP developed here is around 20% lower than the GGDC's estimate of total GDP. At the same time, the estimate of non agricultural private sector workers presented in this analysis is only around 10% lower than the GGDC's estimate of total employment. The exclusion of the same sectors in the United States reduces both observed employment and income by around 20%. This would suggest that the observed Australian productivity level shifts downward because of the exclusion of these sectors. This downward shift in the Australian productivity data establishes the second caveat on the results of the analysis presented later in this paper.

Human capital

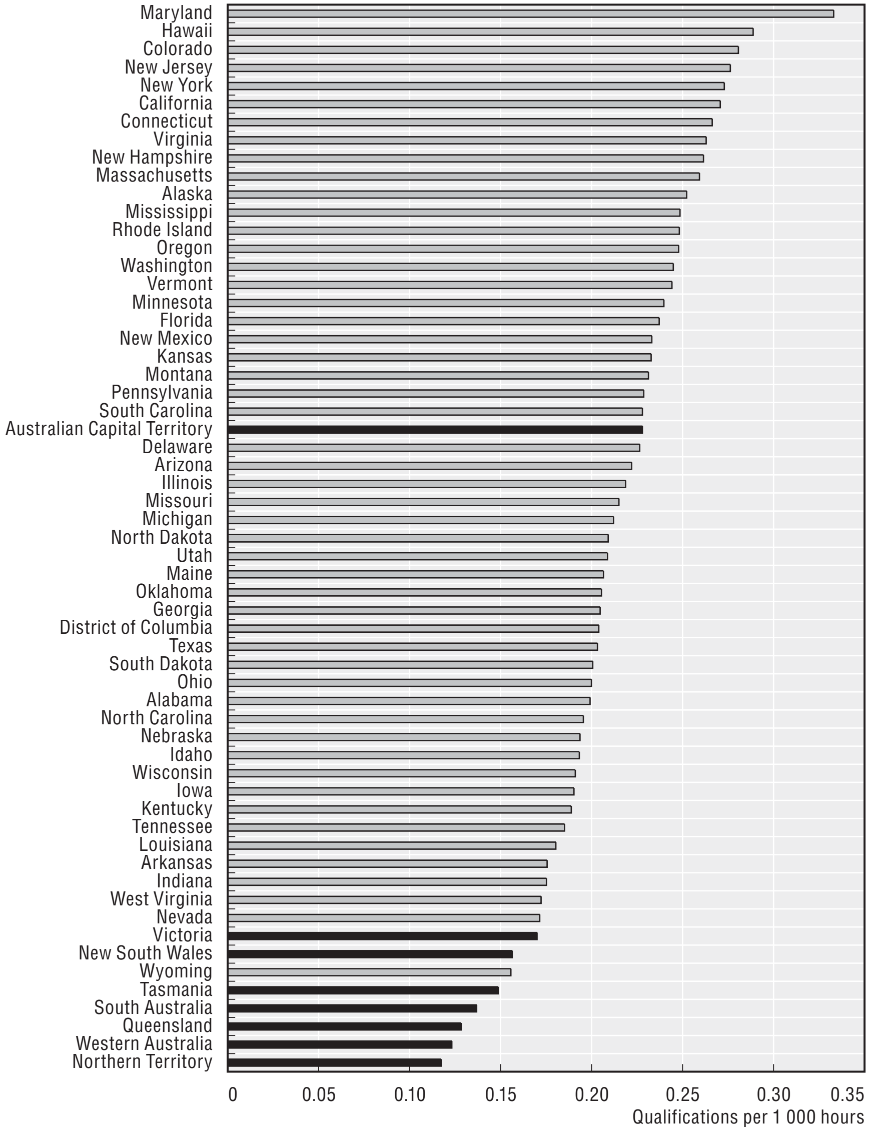
Human capital can include the stock of research, the range of skills, or even the ability to distribute ideas in an economy. This analysis simply uses the number of people holding a bachelor's degree or better as an indicator of the stock of human capital.[7] These data were available at a state level in both the United States and Australia. Figure 3 presents US and Australian human capital per 1 000 hours worked.[8]

Figure 2. **Output per hour worked by state: United States and Australia, 2001**



Source: Bureau of Economic Analysis, *www.bea.gov* and ABS State Accounts (ABS Cat. 5220).

Figure 3. **Human capital per 1 000 hours worked by state: United States and Australia, 2001**



Source: US Census Bureau, *www.census.gov* and Education and Work, (ABS Cat. 6227).

ESTIMATING PROXIMITY AND THE LABOUR PRODUCTIVITY EQUATION

An indicator of proximity

In this analysis, the proximity variable is the key variable of interest. The intention of the variable is to capture the proximity of the state to world output. The hypothesis is that closeness to output presents scale opportunities and spill-overs for firms in a state and that this, in turn, enables a higher level of productivity, other things held constant.

One option for establishing an indicator of proximity may simply be to arbitrarily define a boundary and aggregate all of the state outputs that fall within that boundary. However, the exclusion of all output beyond that boundary and the arbitrariness of the boundary itself encouraged the definition of a better alternative.

The alternative used in this analysis aggregates "decayed" outputs of the economies in the dataset where the decay depends on their distance from the state of interest. Formally, the proximity indicator is defined in equation (4):

$$\zeta_i = \sum_{j=1}^{j=n} Y_j \, d_{ij}^{-\alpha} \qquad [4]$$

The sample consists of $j = 1,\ldots,n$ "economies", which are either Australian or US states or other countries. ζ_i is the proximity indicator for state i, Y_j is the output of economy j and $d_{ij}^{-\alpha}$ is the distance to economy j weighted by α.

The dataset that was used in the creation of this variable included each of the US and Australian states, as well as each of the other countries in the world for which data were available. The most recently available data for the construction of an international proximity indicator were for the year 1998. Distances were calculated as the distance in kilometres between each capital city.

Estimation of equation (3) can be undertaken in a straightforward way using ordinary least squares. However, this type of estimation makes it necessary to make an assumption on the value of α in equation (4) as well as making an assumption on the distance of the state from its own output.

This second assumption directly affects the importance of the state's own output in the calculation if its proximity indicator. If the distance to self (d_{ii}) is too low, the indicator will be too heavily weighted by the own state output, which could be a source of endogeneity in the model. If the distance to self is too high, the indicator will neglect the state's own output, which is the primary source of scale as the state is obviously most proximate to itself.

Therefore, in this analysis, two estimation steps are used. First, both α and the distance to own GDP, d_{ii}, are estimated alongside the coefficients in the productivity equation. Following an estimation of α and d_{ii}, a proximity indicator is constructed for each state. This proximity indicator is then used in ordinary least squares estimations of the parameters β'.

In the first step, β', α and d_{ii} are parameters to be estimated by maximum likelihood using the following specification with a standard normal distribution of the error.

$$\log\frac{Y_i}{L_i} = \beta_0 + \beta_1 \log\frac{K_i}{L_i} + \beta_2 \log\frac{H_i}{L_i} + \beta_3\zeta_i + \beta_4 Aus + \varepsilon_i \qquad [5]$$

$$\zeta_i = \sum_{j=1}^{j=n} Y_j \, d_{ij}^{-\alpha}$$

The estimated proximity indicators for each of the states in the analysis are presented in Figure 4. These indicators seem to accord with *a priori* expectations. That is, states such as New York, New Jersey and California are especially proximate to economic output, as are their surrounding states. The Australian states, however, are further away from world economic output. Notably, though, the large output of New South Wales makes it closer to world output than a small number of the most remote states of the United States.

Model results

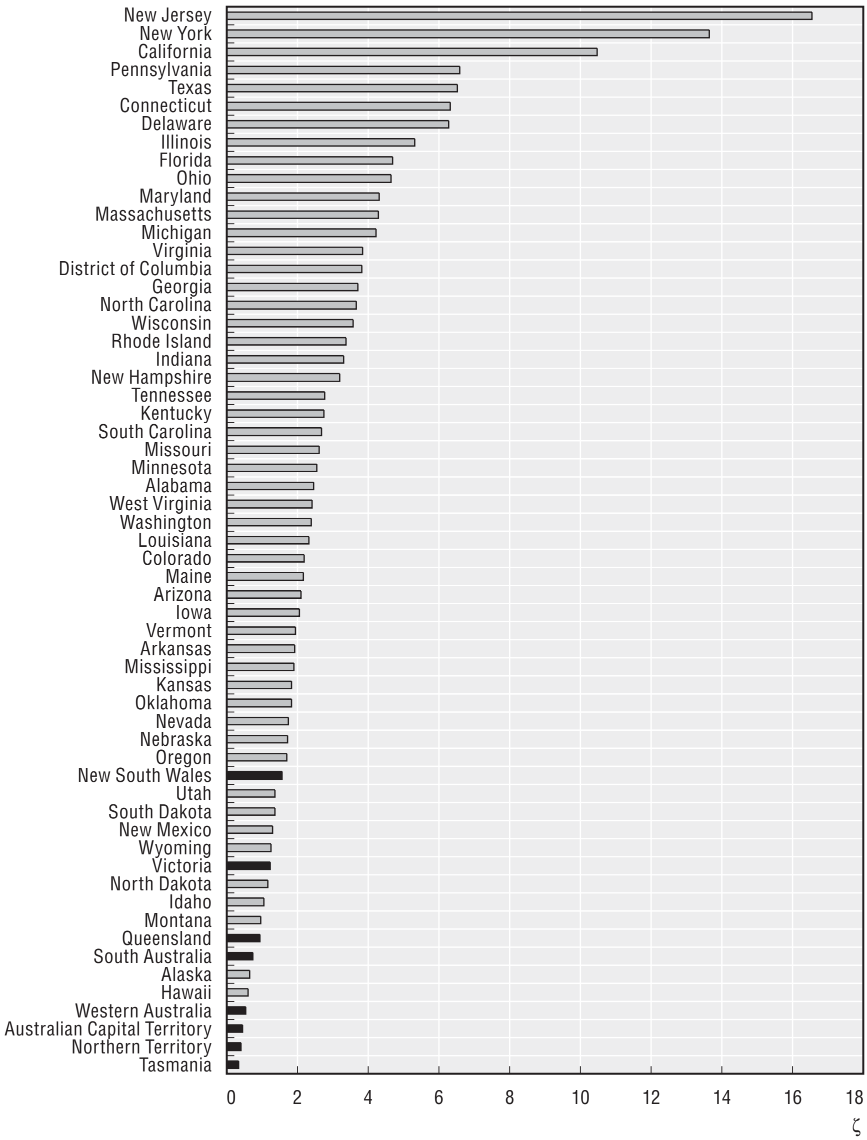
Table 1 presents the set of estimates from ordinary least squares regressions of variations of equation (1). Some of these regressions use the proximity indicators presented in Figure 4.

Equation A presents estimates for the coefficients in the simple model of output. Coefficients on both the capital to labour ratio and the human capital to labour ratio are positive, as expected. However, the insignificance of the capital to labour ratio is a matter of concern, especially given the importance of the capital to labour ratio in the underlying economic model of labour productivity. This reinforces the cautions outlined earlier on the interpretation and use of the headline result of this paper.

Equation B includes the dummy variable identifying the observations that are from Australia. Both of the capital-to-labour ratios have reduced significance, while the dummy variable is not significant. While the lack of statistical significance of the coefficient on the dummy variable urges caution in the coefficient's interpretation, the negative sign does support the expectation that there are reasons beyond the difference in the capital to labour ratios that explain Australia's productivity gap with the US.

Equation C presents the first of two sets of results that include the proximity indicator developed earlier in this section.[9] This coefficient on the proximity indicator has a positive sign, which suggests that the greater the level of output near the state, the greater is the level of labour productivity. Also apparent in this regression is the further reduction in significance of the capital to labour ratio coefficients, which is worrying given the importance of the capital to labour ratio in the economic model. The reduction in explanatory power of these variables is also offset by the more significant coefficient on the proximity indicator and may be a result of multicollinearity with the proximity indicator.

Figure 4. **Proximity indicator with optimal alpha and distance to own output values**



Finally, equation D has a marginally better goodness of fit than equation C, though as with the inclusion of the Australian dummy variable in equation B, the explanatory power of the capital to labour ratios is reduced. Again, the standard

Table 1. **Regression results**

Variable	A	B	C	D
Constant	3.861	3.861	3.742	3.741
	(12.388)***	(12.282)***	(13.385)***	(13.279)***
Log(K/L)	0.087	0.081	0.041	0.031
	(1.483)	(1.261)	(0.759)	(0.533)
Log(H/L)	0.374	0.357	0.222	0.193
	(4.023)***	(2.901)***	(2.427)**	(1.648)
Proximity			0.027	0.027
			(3.928)***	(3.910)***
Australia		–0.018		–0.029
		(–0.221)		(–0.400)
R-squared	0.265	0.266	0.426	0.428
RESET	2.000	3.441	2.810	3.427
Heteroskedasticity	0.932	0.797	0.855	0.760

Note: Numbers in brackets are t-statistics. *** indicates significance at the 1% level, ** indicates significance at the 5% level, * indicates significance at the 10% level. RESET and Heteroskedasticity (White's test) are F-statistics.

Table 2. **Correlation coefficients of the variables**

	Proximity	Human capital
Physical capital	0.713	0.920
Human capital	0.723	

error on the coefficient of this dummy variable is sufficiently high to suggest that the coefficient is not reliable.

Each of the RESET tests shows no signs of misspecification. F-statistics from White's test also suggest that the regressions do not suffer from heteroskedasticity. Correlations between the variables are presented in Table 2. These suggest that there may be multicollinearity, which will affect the standard errors of the variables. While multicollinearity is generally expected in the estimation of a Cobb-Douglas equation, the correlations between the capital indicators and the proximity indicators may deserve further investigation. This is because distance may also increase the transaction costs associated with factor accumulation.

DISCUSSION

This analysis has provided a number of simple equations of state productivity levels in an attempt to identify the extent to which the proximity to economic mass affects productivity. The coefficient on the variable that captured this proximity was positive and significant. The effect of the proximity indicator in the regressions is evidenced by shifting it by one standard deviation from its mean, which results in a 6% shift in the expected level of labour productivity.

Using the parameters and variables presented in this paper, it is possible to calculate the proportion of the productivity gap between Australia and the United States that is explained by Australia's geographic isolation. An average proximity indicator for Australia can be calculated as:

$$\zeta_{Aus} = \frac{\sum_i \zeta_i L_i}{\sum_i L_i} \quad i \in Aus \qquad [6]$$

The average proximity can then also be calculated for the United States. This calculation weights proximity by the total number of hours that are worked in a state. It is then possible to calculate the labour productivity difference that is accounted for by the difference in this proximity indicator as:

$$\ln\left(\frac{Y_{USA}}{L_{USA}}\right) - \ln\left(\frac{Y_{Aus}}{L_{Aus}}\right) = \beta_3 \left(\zeta_{USA} - \zeta_{Aus}\right) \qquad [5]$$

which simplifies to equation (8), where y represents labour productivity:

$$\frac{y_{USA}}{y_{Aus}} = e^{\beta(\zeta_{USA} - \zeta_{Aus})} \qquad [8]$$

Using equation (8) and the results and data outlined earlier, the ratio of US labour productivity to Australian labour productivity that arises in the model purely from differences in the proximity indicator is 1.13. The actual ratio of US labour productivity to Australian productivity in the dataset is 1.34, which suggests that differences in proximity account for just under 45% of the difference in labour productivity levels between the United States and Australia.

Of course, this calculation should be treated with caution. However, the results of further sensitivity analysis do suggest, though, that distance may be accounting for a notable part of the labour productivity gap between Australia and the United States.[10] Importantly, these results also suggest that there are other reasons for Australia's productivity gap with the United States beyond simply the scale and spillover effects that the US economy benefits from.

CONCLUSION

This paper began by suggesting that Australia's internal and external "tyranny of distance" may limit the extent to which Australia can close the productivity gap with the United States. In regressions of labour productivity on an indicator of proximity (which captures a state's closeness to world economic output) along with physical and human capital, the coefficient on proximity was positive and significant. This coefficient suggests that the difference in the average proximity indicators for Australia and the United States accounts for around 45% of the labour productivity gap. This further suggests that even over great distances (greater than those identified in standard agglomeration economics), there may be significant external effects from being located near centres of output.

However, there remain a number of results that deserve further attention. Of particular concern is the insignificance of the capital-labour ratio, which is probably linked to the difficulty of getting reasonable measures of the capital stock at the state level.

As this is only an initial investigation of the effect of the distance from world output on state productivity levels, there remains a range of possible future directions for extending this empirical work, including:

- the creation of a larger dataset that allows the construction of better capital stock data;
- investigating the possibility of using a time dimension in the analysis to explore the effect of other policy related variables while controlling for geography;
- using effective economic distance (which incorporates transport and communication costs) rather than simple geographic distance in the calculation of the proximity indicator;
- the inclusion of more spatially disaggregated data that allows a more complete indication of internal proximity;
- the comparison of the industry structure of states and the identification of similarities and differences in labour productivity attributable to those differences;
- further diagnostic testing, including tests for spatial autocorrelation and endogeneity; and
- the investigation of alternative methods for constructing indicators of global proximity.

However, this work has provided some initial evidence that there is a link between the proximity of a state to output and labour productivity and that Australian states may be disadvantaged because of their distance from global centres of output and because of their distance from each other. Indeed, the proximity of a state to economic activity may need to be considered as a further condition affecting Australia's potential labour productivity level relative to other countries.

To be clear, this result does not suggest that there is an inevitable ceiling for Australia's level of labour productivity. Australia's potential for productivity growth can be decomposed into the potential for Australia's productivity frontier to continue to expand (through innovation and new technologies) and Australia's capacity to reach its productivity frontier. The result of the analysis outlined in this article suggests that Australia's productivity frontier might be somewhere inside that of the United States, but it does not give any reason to doubt that Australia's frontier will continue to expand at the same rate as that of the United States. This expansion will continue to be driven by the ongoing creation of new technologies and innovative work practices, both in Australia and around the world, and the adoption of these technologies and practices in Australian workplaces.

It is also likely that the impact of distance has been and will continue to decline over time. This is clearly true in particular cases, such as in the transport of refrigerated goods and information. Ultimately, though, it is important to note a particular corollary of this work, which is that at least half of the productivity gap with the United States is not explained by geography. This implies that there is considerable scope for Australia to still reach its own productivity frontier and that policy settings may have an important role to play in reaching this frontier.

Notes

1. A summary of the data is available from the author on request.
2. For instance, in 2000, around 27% of Australian workers were part-time workers while only around 13% of the US workforce had the same status.
3. "Super-sectors" are an aggregation by the United States Bureau of Labor Statistics of similar industry sectors using the North American Industry Classification System.
4. The scaling of the data had a negligible impact on the key marginal effects presented later in this paper.
5. An Australian/US dollar exchange rate conversion was also evaluated. In 2001, the difference between the PPP rate and exchange rate was significant. However, converting the capital stock values at exchange rates did not have a noticeable effect on the key marginal effect of interest (*i.e.* the effect of proximity on productivity).
6. Converting output at exchange rates widened the productivity gap significantly. Using an exchange rate conversion of Australian state outputs, Australian labour productivity was around 54% of the United States in 2001. This also reduced the proportion of the gap explained by the location of Australia's states.
7. US data were restricted to the number of people *over* 25 *years* holding a bachelor's degree or better.
8. These data suggest that Australia has a significantly lower stock of human capital than the United States. However, there are signs that this is changing. In work exploring the productivity gap between Australia and the United States, Rahman (2005) notes that while the United States has "traditionally placed more emphasis on the achievement of at least an upper secondary education … the Australia-US gap in educational attainment has … narrowed in the most recent cohorts" (p. 33).
9. The proximity indicator variable was divided by 1 000 prior to estimation.
10. Further sensitivity analysis to changes in the values of α and d_{ii} is available from the author on request.

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