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Pathways to performance: an examination of entry pathway and first-year university results

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ABSTRACT

Although diversity at universities has increased dramatically over the past 150 years, many groups are still under-represented relative to their proportion in the general population. Initiatives to improve diversity have included the increased use of entry pathways other than direct admission from secondary school. As admissions via these alternative entry routes have increased, concerns have grown that alternative-entry students are not well prepared for university study. Here, we describe the outcomes for students entering university via one alternative entry pathway and compare them with those of students entering from secondary school. We used quantile regression with restricted cubic splines to examine the relationship between secondary school performance (quantified by the Australian Tertiary Admission Rank; ATAR), pathway of entry to university, and performance during first year university. Entry pathway significantly affects the conditional distribution of first-year marks. Outstanding performance is largely confined to students entering university from secondary school (Year 12 entry), rather than from an institution for technical and further education (TAFE). Concomitantly, for any given ATAR, the risk of failure is higher amongst Year 12 entry students than among TAFE entry students. The results have substantial implications for changes in admission criteria and for the public funding of universities.

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University admission pathway; quantile regression; student potential; Australian tertiary admission rank, ATAR, admission criteria

Introduction

In the course of a little more than a century and a half, the university-student body in most English-speaking and Western European nations has changed beyond recognition. Under pressure from market forces, government policies, and shifting community attitudes, university student populations have become increasingly heterogeneous and increasingly representative of the general population of the countries in which they are located (Andreu & Brennan, 2012; Moodie, 2015; Rossi, 2009; Simmons, 1903). The heterogeneity extends to factors that include sex, ethnicity, age, first-language, and social class (see, for example, Organization for Economic Cooperation and Development [OECD], 2008, 2016).

Whereas in 1850 it was generally held that “women were intellectually incapable of benefiting by higher instruction” (Simmons, 1903, p. 186), by 1900 almost 47,000 women were enrolled in university-level colleges in the United States and by 1979, the number of women students in the United States exceeded the number of men (Bureau of Census, 1981; see table No. 266, p. 158). In Australia, it took until 1987 for the number of women in higher education to exceed that of men (Department of Education

& Youth Affairs, 2000) but today, the sex-ratio is 137 women per 100 men and rising (Department of Education & Training, 2016). Similarly, it was only in 1957 that the first recorded Aboriginal person, Margaret Williams, enrolled in a course at an Australian university ("Aboriginal girl matriculates", 1957) yet by 2015 there were 16,108 higher education students in Australia who identified themselves as being of Aboriginal or Torres Strait Islander origin (Department & Education & Training, 2016).

Much of the increase in the diversity of the student population over the past century was driven directly by demand endogenous to the under-represented groups themselves, and was achieved by removing legal or administrative barriers (such as a prohibition on the entry of women) rather than by changing the academic requirements for entry to university. Over the past 30 years, the impetus to increase access to higher education by under-represented groups has largely been driven by governments, which view an increased level of participation in higher education as an essential prerequisite for national economic advancement. In response, universities have made changes to their admission processes. In a recent history of equity policy in Australian higher education, Martin (2016) observed that:

With the abolition of [Australian university] fees in 1974, it was believed that the mix of students in universities would be broadened to include a higher proportion of socio-economically disadvantaged students. Unfortunately this did not happen, mainly because there were few accompanying changes to admission criteria by universities to allow for a less academically prepared clientele. (p. 21)

Following the realization that the abolition of fees did not, of itself, markedly improve access to higher education by under-represented groups, there have been numerous efforts to expand the routes of entry to university beyond that of direct admission following the completion of secondary school. For example, as early as 1990 the Australian Government advocated the development of "special entry arrangements for socio-economically disadvantaged groups" (Department of Education, 1990, p. 2), noting particularly that:

Many school leavers from socio-economically disadvantaged backgrounds do not consider going on to higher education. Those who consider further education are more likely to enrol in TAFE courses [i.e., courses at colleges of technical and further education]. One way of helping these students to upgrade their qualifications or to re-train in a related area is establishing transfer arrangements so that students can move from TAFE to higher education. (Department of Education, 1990, p. 18)

A similar policy approach has been evident in the United Kingdom with a recent review concluding that

widening participation [in higher education] will require enhancing existing, and developing new, routes into and pathways through higher education that are appropriate for, and relevant to, a broader range of students and not just those school leavers with A-level qualifications. (Foster, 2009, p. 10)

Experiments with so-called "alternative routes of entry" to university have also been conducted in New Zealand (e.g., Turner, Shulruf, Li, & Yuan, 2012) and Ireland (European Commission/EACEA/Eurydice, 2014) with varying degrees of success.

Although the traditional route, of direct admission following the completion of secondary school, is still the most common pathway taken by undergraduate university entrants in Australia, a growing number of students are now being admitted through alternative admission pathways, and particularly via the route that leads from secondary school to a college of technical and further education (TAFE) and thence to university (Tertiary Education Quality & Standards Agency, 2017). In 1994, for example, only 5.8% of commencing undergraduate students in Australia were admitted to university on the basis of their study at a TAFE college but by 2006, 10.1% of admissions were on that basis (Bradley, Noonan, Nugent, & Scales, 2008, p. 192) with that percentage now having been stable for a decade (Tertiary Education Quality & Standards Agency, 2014, p. 13, 2017, p. 16).

Despite government emphasis on alternative admission pathways as a way of improving access for under-represented groups of students, especially for those from socio-economically disadvantaged backgrounds, there has been growing concern, at least in the news media, that universities are now admitting students who are poorly prepared for university study (Bagshaw & Ting, 2016; Hare, 2015, 2016; Norton, 2015, p. 21 January). There are at least four adverse consequences – all of which represent (potentially correctable) inefficiencies – that might result from admitting poorly prepared students:

- (1) The students obtain poor grades;
- (2) University teaching resources are stretched by the additional demands that weaker students place on the system;
- (3) Assessors come under pressure to give passing grades to poor students, thereby lowering the perceived value of a degree; or
- (4) The students fail to complete their degrees.

Whether or not any of these risks are realized in practice is an empirical matter.

Although the association between the performance of students at secondary school and their subsequent performance at university has been of enduring interest (e.g., Bagg, 1968; Dobson & Skuja, 2005; Everett & Robins, 1991; Jones & Siegel, 1962; Kelly & Fiske, 1951; Lavin, 1965; Mora & Escardíbul, 2008; Wagner & Strabel, 1935; West, 1985), the focus of research has been almost entirely on predicting the average outcome of students at university. In this paper, we examine the first risk – the possibility of obtaining poor grades – by investigating the first-year university performance of students who entered Monash University, one of Australia's top-tier universities, via the TAFE entry pathway or via the Year 12 entry pathway. Rather than limiting our examination to average performance, we consider the relationship between school performance and the likelihood of superior university outcomes, and the relationship between school performance and the risk of failure at university.

We commence by developing an ordinary least-squares (OLS) regression model (Allen, 1997) to describe the relationship between two covariates (secondary school performance and entry pathway) and first-year university performance. We then consider the inadequacies of both the straight-line regression fit and the focus on the conditional mean before proceeding to create a quantile-regression model using restricted cubic-splines (Harrell, 2001). The administrative and policy implications of the models are considered in the concluding section. Throughout the paper, our emphasis is on describing the observed relationships between the variables of interest, rather than on hypothesis testing.

Monash University in context

Monash University is a member of the so-called “Group of Eight” (Go8), a coalition of Australia's top ranked research-intensive universities. With a population of 39,964 students it was the largest of the Go8 universities in 2010. In 2010, about 10.7% of Monash University students were from socio-economically disadvantaged backgrounds – somewhat below the national average of 14.5% but above the representation of students from socio-economically disadvantaged backgrounds at the remaining Go8 universities (8.4%). Further information about the student population of Monash University as compared with other universities in 2010 is presented in Table 1.

Data and methods

We obtained de-identified data for 18,262 students who were admitted to Monash University via either the TAFE entry or Year 12 entry pathways between 2007 and 2010 and who completed at least one year of study. The data included information about the Australian Tertiary Admission Rank (ATAR), weighted-average first-year mark, and pathway of entry into university of each student. To protect student privacy, the university declined to provide more detailed data, including year of admission.

Measures

Weighted-average first-year mark (WAFYM)

The calculation of weighted average marks, generically, is described on the Monash University web-site (Monash University, 2013). When one considers only marks for first-year units, the calculation of weighted average first-year mark reduces to:

Table 1. Monash University in context in 2010. Statistics comparing Monash University with other universities in the Group of 8 and with national averages.

Parameter	Monash University	Other Group of 8 universities ^a (mean)	All Australian universities (mean)
Undergraduate students (n)	28,400	18,690	15,264
Postgraduate students (n)	11,564	8,441	5350
Percentage postgraduate	28.93	31.11	25.30
Low socio-economic status undergraduate participation rate ^b (per cent)	11.29	8.42	15.48
Indigenous undergraduate student participation rate (per cent)	0.32	0.87	1.32
Non-English speaking background ^c undergraduate student participation rate (per cent)	4.35	3.39	3.14
Regional and remote undergraduate student ^d participation rate (per cent)	14.39	10.12	19.99

Notes: Student enrolment numbers are taken from Australian Government Department of Education and Training (2017). Participation rates are from Australian Government Department of Education (2013). In contrast to the percentages reported in the main text, the participation rates in the table are for undergraduate students only.

^aAustralian National University, University of Adelaide, University of Melbourne, University of New South Wales, University of Queensland, University of Sydney, University of Western Australia.

^bParticipation rate is a statistic published by the Australian Government Department of Education and represents the number of students in the target population, divided by the total number of on-shore domestic undergraduate students, expressed as a percentage.

^cA student from a non-English-speaking background (NESB) is a domestic student, who arrived in Australia less than 10 years prior to the reference year (in this case 2010), and in whose home a language other than English is spoken..

^dA student from a regional or remote background is one whose permanent home address is within an area defined to be regional or remote under the Australian Statistical Geography Standard (Australian Bureau of Statistics, 2016).

$$WAFYM = \frac{\sum_{u \in \text{Units undertaken}} m_u \times c_u}{\sum_{u \in \text{Units undertaken}} c_u}$$

where WAFYM is the weighted-average first-year mark, m_u represents the mark that a student receives for unit u , and c_u represents the credit points that the unit is worth.

ATAR

The Australian Tertiary Admission Rank (ATAR) of a student is derived from a weighted sum of marks that the student obtains for a selection of subjects completed at Year 12 level at secondary school. The ATAR is intended to indicate the percentile rank of a student with respect to a reference cohort, that cohort being the population of students who entered Year 7 at the same time as the relevant student and including those Year 7 entrants who did not subsequently complete Year 12. ATARs are reported in 0.05 percentile bands, to a maximum ATAR of 99.95. Further technical details of the ATAR can be found elsewhere (Universities Admissions Centre, 2009).

Entry pathway

A student who obtains an ATAR of 70 or greater is eligible to apply for entry to Monash University directly from Year 12 although competition for places might mean that the student is not offered a place at the university despite having obtained a qualifying ATAR. Students who were admitted to Monash University directly from Year 12 are referred to in this paper as “Year 12 entry” students.

A student whose ATAR does not qualify them for direct entry to Monash University might choose, either immediately or after a delay of years, to attend an institution of technical and further education (TAFE). A student who then obtains a qualification from a TAFE may subsequently apply to Monash

University for consideration for admission. Additionally, a student might choose to undertake further study at a TAFE despite having obtained an ATAR that qualified them for entry to Monash. Approximately 7.5% of students admitted to Monash University enter via the TAFE pathway (Willis & Joschko, 2012). In this paper, such students are referred to as “TAFE entry” students.

Students who complete a TAFE qualification are not awarded a new ATAR. The ATAR for a TAFE entry student is the ATAR that they obtained at the end of Year 12 of secondary school, prior to commencing at a TAFE.

Data analysis

The analysis in this paper starts with a straightforward ordinary least squares (OLS) regression analysis – broadly similar to others’ analyses (cf. Birch & Miller, 2007; Farley & Ramsay, 1988) – predicting the conditional mean WAFYM from ATAR and entry pathway. The OLS results are then contrasted with a series of quantile regression analyses that incorporate restricted cubic splines (Durrleman & Simon, 1989) and model the same basic relationship between WAFYM, ATAR and entry pathway.

The purpose of quantile regression is to predict a quantile of the dependent variable (here, WAFYM) conditional on one or more independent variables (here, ATAR and entry pathway), rather than to predict the conditional mean of the dependent variable. Quantile regression allows us to develop a richer and more robust description of the data than is available from OLS, especially in that it can show the change in the response variable across the range of the independent variables. Further conceptual and technical information regarding quantile regression and restricted cubic splines is presented in the Appendix.

Software

The analyses and graphs were all produced using the open source, R statistical software (R Core Team, 2013). Some of the graphical displays were produced using the “lattice” package (Sarkar, 2008), others were produced using “ggplot” (Wickham, 2009). Quantile regression analyses utilized the R package “quantreg” (Koenker, 2013); restricted cubic-splines were obtained using package “rms” (Harrell, 2001).

Ethics

The analyses were based on publicly available de-identified data. Ethical review was neither required nor sought.

Results

Of the 18,262 records, 16,831 records were for students who entered Monash University from Year 12 and 1,431 records were for students entering from a TAFE institution.

Univariate distributions

Univariate distributions of the WAFYMs and ATARs of students in each entry group are shown in Figure 1.

The distribution of ATAR scores within each of the two entry groups is clearly very different. In the TAFE entry group, the distribution is approximately normal, whereas the distribution of ATARs in the Year 12 entry group shows clear evidence both of the influence of the usual ATAR cut-off for entry into Monash University (ATAR > 70) as well as of the fact that available places are offered to students with higher ATARs before being offered to those with lower ATARs. The resulting oversampling from the high end of the ATAR range produces the negative skew in the distribution. In contrast to the ATAR distributions, the WAFYM distributions for the two entry groups are of very similar shape. Both are negatively-skewed with a peak around a WAFYM of 70.

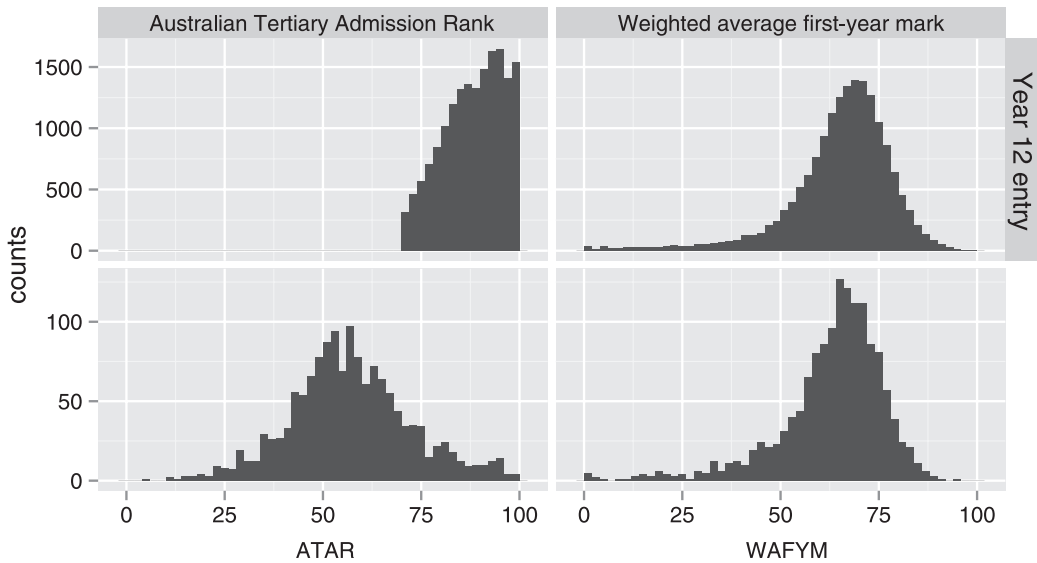


Figure 1. Histograms of the distribution of ATARs and of weighted-average first-year marks (WAFYMs) among Year 12 entry and TAFE entry Monash University students.

Table 2. Parameters for the estimation of WAFYMs from ATAR and entry pathway using straight-line OLS regression. Standard errors are shown in parentheses.

Parameter	Affected variables	Estimate	<i>t</i>	<i>p</i>
β_0	Intercept (at ATAR=70)	51.642(0.243)	212.83	<0.001
β_1	ATAR	0.742(0.012)	59.98	<0.001
β_2	ENTRY(TAFE)	15.032(0.488)	30.77	<0.001
β_3	ATAR×ENTRY(TAFE)	−0.451(0.244)	18.50	<0.001

Predicting first-year grades: linear OLS regression

We commence our analysis with the prediction of weighted-average first-year marks from a combination of both ATAR and entry-pathway, fitting separate regression lines for the Year 12 and TAFE entry groups. Following Singer and Willett (2003), ATAR values were recentred at 70 to improve the interpretation of the results. With recentring, the estimating equation may be written as

$$E(WAFYM_i | ATAR_i, ENTRY_i) = \beta_0 + \beta_1 (ATAR_i - 70) + \beta_2 ENTRY_i + \beta_3 ENTRY_i (ATAR_i - 70) + \varepsilon_i$$

where i indexes students, β_0 represents the predicted conditional mean WAFYM for Year 12 entry students with an ATAR of 70, β_1 represents the slope of the regression line for Year 12 entry students, β_2 represents the difference between parameter β_0 and the predicted conditional mean WAFYM for TAFE entry students with an ATAR of 70, and β_3 represents the difference between parameter β_1 and the slope of the regression line for TAFE entry students. ENTRY is a dummy variable coded as 0 = Year 12 entry, 1 = TAFE entry.

The parameter estimates obtained using ordinary least-squares straight-line regression are presented in Table 2.

From the estimates, two prediction equations – for Year 12 entrants and TAFE entrants respectively – can be derived:

$$E(WAFYM_i | ATAR_i, \text{Year 12 entrant}) = 51.6 + 0.74 \times (ATAR_i - 70),$$

$$E(WAFYM_i | ATAR_i, \text{TAFE entrant}) = 66.67 + 0.29 \times (ATAR_i - 70)$$

Figure 2 shows the WAFYMs for both Year 12 entry and TAFE entry students, plotted as a function of ATAR, with the regression lines superimposed.

The results show clearly that ATAR makes a significant contribution to the prediction of the conditional mean of weighted-average first-year marks for both Year 12 and TAFE entry students but that the two groups of students differ from one another in important respects. The conditional-mean WAFYM of students with an ATAR of 70 (the centring point and the lower cut-off for Year 12 entry) is some 15 points ($\beta_0 + \beta_2$) higher for TAFE-entry students than for similarly ranked students entering university from Year 12 (β_0). Moreover, while WAFYM is predicted to increase by 0.74 (β_1) percentage points for each unit increase in ATAR amongst Year 12 entrants, the predicted increase in WAFYM for each unit increase in ATAR is only 0.29 ($\beta_1 + \beta_3$) percentage points for students entering university from TAFE.

Although the results reported in this section are broadly consistent with those from several other Australian studies (summarized by Birch & Miller, 2005) there are at least three deficiencies with the fitted OLS model. First, for ATAR values above about 95 the WAFYMs for Year 12 entrants increasingly deviate from the fitted line; see Figure 2. Second, contrary to the OLS assumption of conditional normality, the distribution of weighted-average first-year marks (conditioned on ATAR) is highly skewed for both Year 12 entrants and TAFE entrants; the WAFYMs are denser in the upper reaches of the distribution, with a long tail of poor first-year marks occupying the range between about 0% and 40%. Thirdly, the data are markedly heteroscedastic, with the variance in WAFYMs decreasing with increasing ATAR, particularly amongst the Year 12 entrants. For example, the variance in WAFYM for Year 12 entry students with ATARs between 70 and 72 is 260 compared with a variance of 78 for Year 12 entry students with ATARs of 98 and above. Both the skew and heteroscedasticity are reflected in the plot of regression residuals against fitted values (Figure 3) where one can see that the residuals are distributed asymmetrically about the horizontal zero line (skew) and are not the same at different fitted values (heteroscedasticity).

The first problem can be addressed by abandoning the assumption that the relationship between ATAR and WAFYM is strictly linear. One possibility would be to fit piece-wise linear segments (an

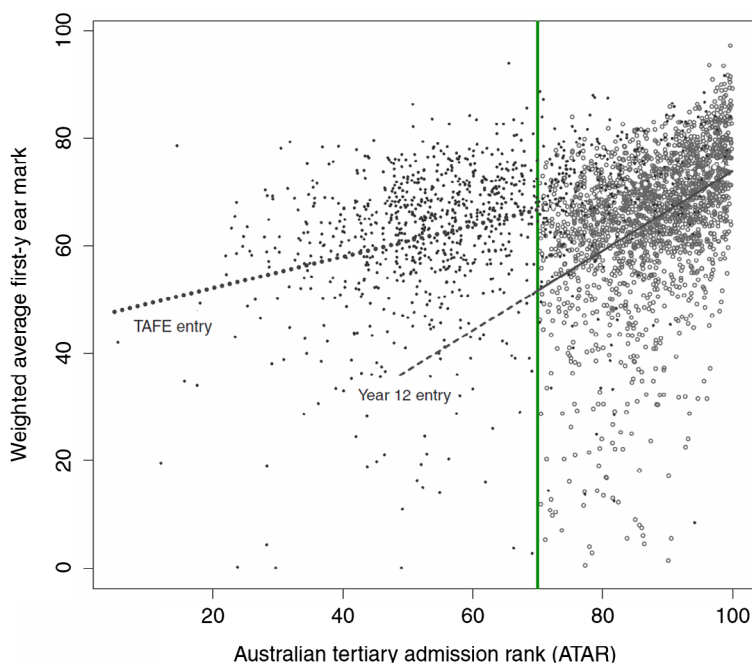


Figure 2. Weighted-average first-year mark (WAFYM) as a function of ATAR for Monash University students admitted directly from Year 12 (open grey circles) or via the TAFE entry pathway (solid black circles). OLS regression lines are shown (Year 12 entry: solid and dashed line; TAFE entry: dotted line) together with the ATAR cutoff for direct entry from Year 12 (vertical line at ATAR = 70). Dashed Year 12 line represents extrapolation beyond the sample data. For clarity, only a subset of points are shown.

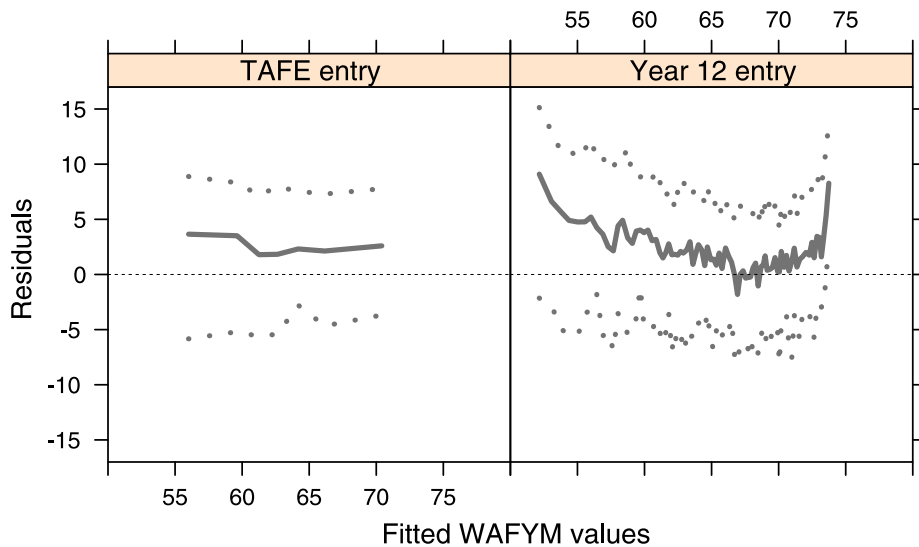


Figure 3. OLS Regression residuals for Year 12 entry and TAFE entry as a function of predicted (fitted) WAFYM values. Median residual values (solid grey line) are shown together with the first and third quartile values (dotted lines).

approach taken by Willis & Joschko, 2012), but we use restricted cubic-splines because of the advantages they offer, not least being that it is unnecessary to assume any specific functional relationship (e.g., piecewise-linearity) between the predicted and independent variables (Harrell, 2001). The remaining problems, associated with the lack of conditional normality and heteroscedasticity, can be overcome by abandoning the assumption that the predicted variable follows a parametric distribution and by using quantile regression methods in place of OLS regression (Hao & Naiman, 2007).

It is worth noting that there are good reasons to suppose a priori that the relationship between a chosen measure of school performance and a measure of university performance will not necessarily be linear. In Australia, for example, measures of university performance are typically based directly on the mark that students obtain in their courses (see, for example, McKenzie & Schweitzer, 2001; Roodenrys, 2008; Thomas, Henderson, & Goldfinch, 2011), and conform, or at least are intended to conform, to an interval scale of measurement (Stevens, 1946). Contrarily, the most commonly used measures of school performance conform only to an ordinal scale of measurement in that they reflect students' cohort rankings (Universities Admissions Centre, 2009). Identifying the linearity or otherwise of the relationship between variables on different scales of measurement is notoriously problematic.

Restricted cubic spline-based quantile regression model

To assess the influence of ATAR on the distribution of WAFYM, we developed separate models for the conditional WAFYM quantiles 0.05, 0.10, 0.25, 0.50 (median), 0.75, 0.90, 0.95, and 0.99 for each of the two entry pathways. The reason for not seeking to develop a model predicting WAFYM from both ATAR and entry-pathway jointly was that the difference in the range of ATAR for Year 12 entry students (ATAR 70–99.95) and TAFE entry students (ATAR 5.35–99.65) would have resulted in models ill-suited to the prediction of WAFYM for either set of students.

Model fitting proceeded via several iterations in the manner recommended by several authors (Cleveland & McGill, 1984; Harrell, 2001; Johnson & Omland, 2004). Models were initially fitted using restricted cubic splines with four knots, at ATAR quantiles 0.05, 0.35, 0.65, and 0.95 (see Harrell, 2001) within each university-entry group. The decision to use four knots was made so as to reduce the possibility of over-fitting the data, particularly in the TAFE entry cohort where the total number of cases was more limited. While the nonlinear components of the restricted cubic splines were significant at $\alpha = 0.05$ for all fitted WAFYM quantiles for Year 12 entry students, they were not statistically significant

for most of the fitted WAFYM quantiles for TAFE entry students. Moreover, despite reaching statistical significance, the nonlinear components of the splines fitted to WAFYM quantiles 0.95 and 0.99 of the TAFE entry cohort were found to be a consequence of overfitting the data, despite initial precautions. The overfitting was evidenced by the fact that the predicted conditional WAFYM for quantiles 0.95 and 0.99 did not increase monotonically and the regression splines included short ATAR intervals where, contrary to theory and prior evidence, the relationship between WAFYM and ATAR was negative, rather than zero or positive. Following Stone and Koo (1985), we refitted those two quantile regression models using three-knot restricted cubic splines, with knots at ATAR quantiles 0.10, 0.50, and 0.90 (see Harrell, 2001). The nonlinear components of the three-knot models did not reach statistical significance. The final set of models (Table 3) comprised straight-line fits at all the WAFYM quantiles of interest in the TAFE entry group, and four-knot restricted cubic spline models at the same WAFYM quantiles for the Year 12 entry group.

Figures 4 and 5 present alternative views of the relationship between predicted WAFYM quantile, ATAR and entry-pathway. Figure 4 shows the full set of quantile regression models for each of the two entry-pathway groups separately, whereas Figure 5 compares the model results for the two entry pathways separately for each quantile of interest. Figure 6 presents quantitative information regarding the slope of the quantile regression lines at different ATAR values.

It can be seen that there are considerable differences between the quantile regression models for Year 12 entry students and those for TAFE entry students. The regression lines for the conditional WAFYM quantiles for TAFE entry students are linear and very roughly parallel in addition to being roughly parallel with the OLS regression line for the conditional mean. The linearity indicates that amongst TAFE entry students the relationship between ATAR and WAFYM is the same across the ATAR range while the parallelarity of the regression lines indicates that the relationship is constant across the range of WAFYMs. This can be seen more clearly in Figure 6 where the slope of the regression lines is plotted as a function of quantile. The line for TAFE entry students, which is the same across the ATAR range, is almost flat, indicating that there is little variation in the slope of the regression lines across the quantiles of WAFYMs. Moreover, it can be seen that the slope of the median regression line (quantile 0.50) is indistinguishable from that of the OLS regression line for the conditional mean.

In contrast, the quantile regression models for Year 12 entry students show two notable features. First, there is a marked degree of non-linearity in the fitted models for Year 12 entry students, with the predicted conditional WAFYM quantiles turning sharply upward when ATAR exceeds about 90 (Figures 4 and 5). Second, the slope of the fitted models for the quantiles of the WAFYM distribution of the Year 12 entry cohort varies markedly across quantiles with the lines tending to be flatter in the upper quantiles than in the lower

Table 3. Slope of fitted quantile regression lines by entry pathway and quantile, at five ATAR values. The regression lines for all TAFE entry quantiles are strictly linear so slope does not vary as a function of ATAR.

Entry	Fitted Quantile	ATAR				
		50	70	80	95	99
Year 12	.05	1.33	1.33	1.34	2.06	2.20
	.10	1.32	1.32	1.21	1.59	1.78
	.25	0.72	0.72	0.66	1.25	1.43
	.50	0.48	0.48	0.45	1.21	1.39
	.75	0.40	0.40	0.37	1.26	1.48
	.90	0.36	0.36	0.33	1.30	1.52
	.95	0.32	0.32	0.31	1.33	1.55
	.99	0.24	0.24	0.24	1.39	1.62
TAFE	.05	0.34	0.34	0.34	0.34	0.34
	.10	0.38	0.38	0.38	0.38	0.38
	.25	0.33	0.33	0.33	0.33	0.33
	.50	0.27	0.27	0.27	0.27	0.27
	.75	0.28	0.28	0.28	0.28	0.28
	.90	0.23	0.23	0.23	0.23	0.23
	.95	0.24	0.24	0.24	0.24	0.24
	.99	0.17	0.17	0.17	0.17	0.17

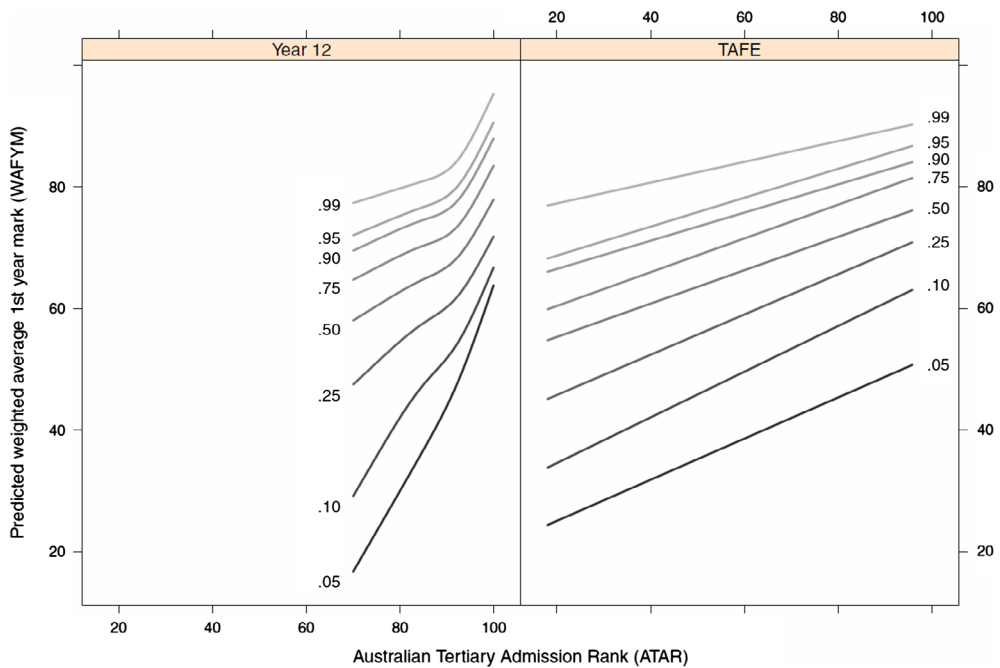


Figure 4. Quantile regression lines by entry-pathway for WAFYM conditional quantiles 0.05, 0.10, 0.25, 0.50, 0.75, 0.90, 0.95, and 0.99.

quantiles. As is evident from the slope-versus-quantile plots (Figure 6), in the lower ATAR range ($ATAR < 90$) the slope of the regression lines for the conditional WAFYM quantiles decreases steadily from quantile 0.05 to quantile 0.99, with the slope of the regression line for quantiles 0.90 and above being very similar to the slope of the conditional quantile lines for the TAFE entry students. In the upper ATAR range ($ATAR > 90$) the regression lines are steeper at all quantiles than in the lower range, indicating a stronger relationship between WAFYM and ATAR for high ATAR students than for low ATAR students. In addition, whilst the slope of the quantile regression lines in the upper ATAR range decreases from quantile 0.05 to 0.25, above that quantile the regression lines are roughly parallel (shown by the flattening of the slope-versus-quantile lines).

Discussion

In this section, we consider the results from each of the analyses in the light of other research that seeks to understand the relationship between university performance, secondary-school results, and other variables. Having concluded our technical discussion, we then focus on the broader implications of our results and return to the specific issue of increasing diversity. Before proceeding to a discussion of our results, however, it is important to note that, in the vast body of literature regarding the relationship between university performance and student characteristics, numerous and diverse variables have been found to be significantly related to university academic outcomes. They include secondary school performance (Kuncel, Hezlett, & Ones, 2001; Zwick & Sklar, 2005), sex (Bridgeman & Wendler, 1991; Dayioğlu & Türit-Aşik, 2007), hours of work (Salamonson & Andrew, 2006), psychological health (Chow, 2007), sleep habits (Trockel, Barnes, & Egget, 2000), type of school attended (Birch & Miller, 2007), number of hours of study (Jackson, Weiss, Lundquist, & Hooper, 2003; Nonis & Hudson, 2006), smoking (DeBerard, Spielmans, & Julka, 2004), and socio-economic status (Hansen & Mastekaasa, 2006; Karmel & Lim, 2013; Ross, Cleland, & Macleod, 2006). Indeed, following a review of 800 meta-analytic studies relating to educational achievement at school, college, and university, Hattie (2009) concluded that more than 130 variables have significant effects on academic achievement. While it would have been

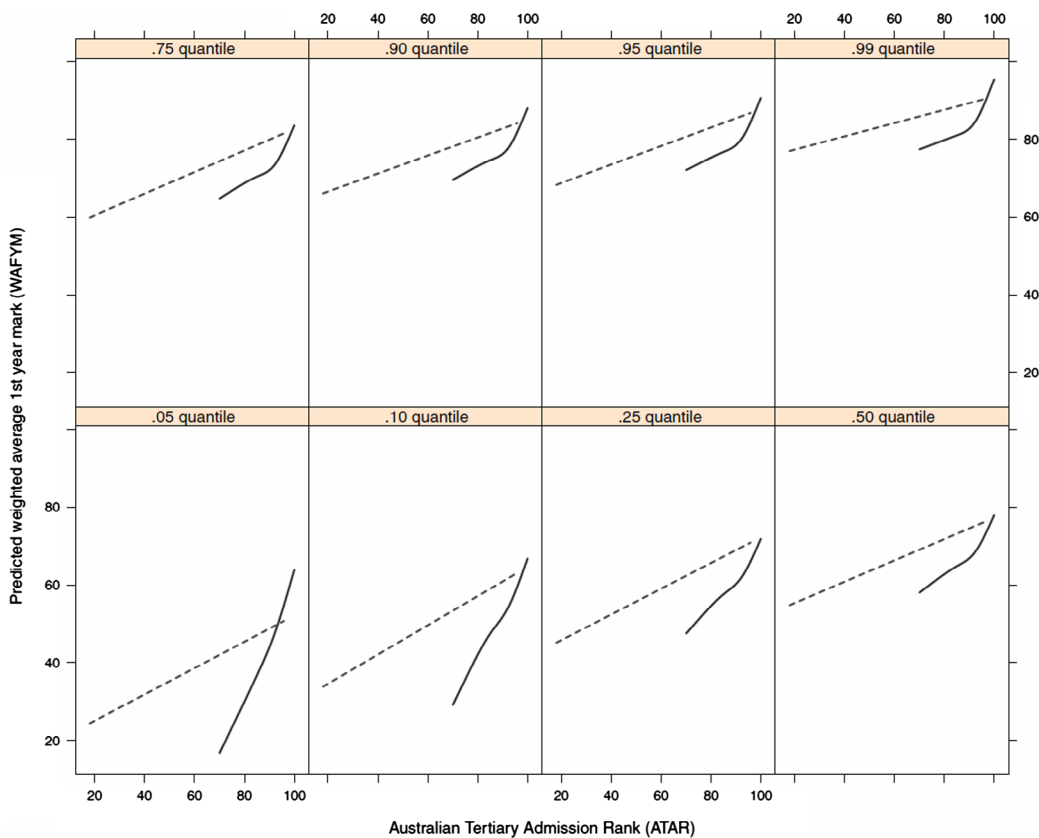


Figure 5. Quantile regression lines for Year 12 entry students (solid lines) and TAFE entry students (dashed lines) for WAFYM conditional quantiles 0.05, 0.10, 0.25, 0.50, 0.75, 0.90, 0.95, and 0.99.

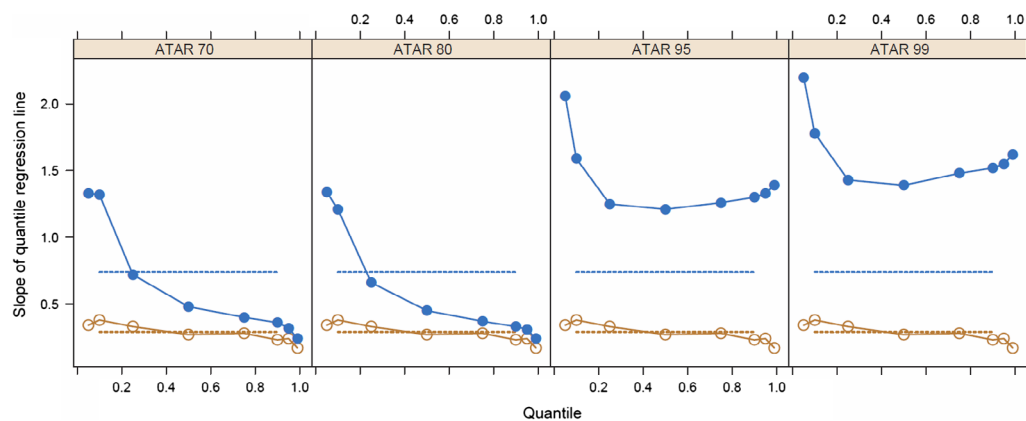


Figure 6. Slope of the regression lines as a function of fitted quantile of weighted-average first-year mark (WAFYM) and admission rank (ATAR). Values are shown for both Year 12 entry students (blue lines, solid blue circles) and TAFE entry students (brown lines, open brown circles) together with the corresponding slopes for the OLS regression lines (Year 12 entry students: horizontal dotted blue line; TAFE entry students: horizontal dotted brown line). Values for TAFE entry students are constant (replicated) across ATAR panels because the straight-line quantile regression models do not vary with ATAR.

desirable to have had access to measures of some, if not all, of those characteristics for the students in our sample, that was not possible for the privacy reasons mentioned in the Data and Methods section of this paper. Moreover, even had such variables been available, there is little guidance available in the literature to indicate which variables should be given precedence in an analysis.

OLS regression

The results from the traditional OLS analysis of the relationship between WAFYM and ATAR confirm previous studies (e.g., Auyeung & Sands, 1994; Birch & Miller, 2006; Dobson & Skuja, 2005; Dockery, Seymour, & Koshy, 2016; Johnes & McNabb, 2004a, 2004b; Li & Dockery, 2014; Stinebrickner & Stinebrickner, 2003, 2008; Win & Miller, 2005) indicating a significant positive relationship between first-year university performance and prior school performance. Additionally, the coefficient values for ATAR in the OLS regression models reported here are within the range of those previously reported.

Weighted average first-year marks are positively correlated with ATAR amongst both Year 12 entry students and TAFE entry students, with the relationship being considerably stronger amongst the Year 12 entrants. Averaged across the ATAR and WAFYM ranges, the weighted-average first-year marks of Year 12 entry students increase by 0.74 percentage points for every one point increase in ATAR, whereas the equivalent increase is only 0.29 percentage points among TAFE entry students. The weaker relationship between WAFYM and ATAR among TAFE entry students than among Year 12 entry students is unsurprising. ATAR and WAFYM can be viewed as a test and re-test of related abilities and it is a long-established result that test-retest reliability (i.e., the correlation between the two test results) decreases with increasing delay between the two tests (Adkins, 1937). For Year 12 entry students in the present study, the delay between ATAR and WAFYM is one year, whereas for TAFE entry students the delay is two years or more and thus allows more time during which the additional effects of maturation and additional learning can operate.

Quantile regression with restricted cubic splines

In contrast to the simple picture implied by the straight-line OLS regression analyses, the spline-based quantile regression analyses provide a rich description of the nexus between university performance, prior school performance and entry pathway. They serve not only to highlight more significant differences between the Year 12 entry students and TAFE entry students than are apparent from the results of the OLS analyses but also to reveal differences in the distribution of WAFYMs that are to be expected from Year 12 students with different ATARs.

Year 12 entry students

While the OLS regression result for Year 12 entry students suggests that they will not perform as well in their first year of university as TAFE entry students with similar ATARs, the results of the quantile regression analyses show that the true situation is more complicated. The complication results both from the change in variance of WAFYMs with changing ATAR (heteroscedasticity) and from the fact that the association between WAFYM and ATAR changes across the ATAR range and does so at all quantiles of WAFYM.

The lower quantiles of first-year performance are very strongly related to ATAR so that the likelihood of a student performing poorly diminishes rapidly as ATAR increases. Although about one in three students with an ATAR of 70 are likely to get WAFYMs below 50, only one in 20 students with an ATAR of 90 will get similar results.

As one moves progressively from the lower to higher quantiles of university performance, so, at least in the lower ATAR range, the association between WAFYM quantile and ATAR decreases (Figure 6). The likelihood that a student with an ATAR of 80 will perform well (WAFYM > 80) in their first year is around 1% and the likelihood rises to only 5% amongst students with an ATAR of 90. However, in the upper range (ATAR > 90) the likelihood of exceptionally good performance rises rapidly and indeed,

truly exceptional performance appears to be confined to those students who are admitted via the Year 12 entry pathway and who also have ATARs above about 97 (Figure 4). Correspondingly, although students who are admitted on the basis of high ATARs can do very poorly, the likelihood of them doing so is low, and quickly becomes even less likely with each increment in ATAR.

TAFE entry students

In contrast to the results for Year 12 entry students, the results for TAFE entry students reflect a simpler relationship between WAFYM and ATAR and the spline-based quantile regression results add little to the traditional OLS regression approach. This is particularly so as the non-linear components of the initially fitted splines were found not to be statistically significant.

As is suggested by Figure 6, the slope of all the quantile regression lines is similar to that of the OLS regression line. The likelihood of very poor, mid-range, and exceptionally good first-year results, all change with ATAR in much the same way and do so evenly across the whole of the ATAR range.

Policy implications of the results for the highest quantiles

Birch and Miller (2006) reported that the slope for the 0.9 quantile line was not significantly different from zero; in other words, the independent variables available to them did not predict changes in the 0.9 quantile level. On that basis, they concluded that offering scholarships on the basis of final secondary-school grade might not be a good idea because, while ATAR (for example) might predict mean WAFYM, it did not give any information about who would do exceptionally well. In contrast, our results indicate that ATAR is strongly related to superior performance in the first-year of university, particularly amongst Year 12 entry students, and that in the very high-ATAR range Year 12 entry students are likely to outperform TAFE students with similar ATARs. At many universities, including Monash, scholarships are awarded for a variety of purposes and based on a range of criteria. Where the purpose of the scholarship is to support those students most likely to excel, our results show that ATAR and entry pathway together serve as strong basis for choosing the scholarship recipients.

Policy implications of the results for lowest quantiles

Extrapolating the quantile regression lines into the range (50–70) below the Monash University admission cut-off suggests that 37% of Year 12 entry students with an ATAR of 65, 42% of Year 12 entry students with an ATAR of 60, and 46% of Year 12 entry students with ATARs of 55 could be expected to fail (i.e., obtain WAFYMs below a pass grade of 50). That inference necessarily relies on two assumptions: first, that the extrapolated linear relationship between ATAR and WAFYM holds when external conditions remain constant, and second, that those external conditions do in fact remain constant and that universities would not be reactive in their response to a greater number of low-ATAR students being admitted. Whether or not the assumptions are met is open to question. Nonetheless, contrary to the opinion of recent Australian commentators such as Devlin (2015), the inconvenient truth conveyed by the empirical evidence from studies such as this one and that of Birch and Miller (2006) is that the ATAR of a student contains significant information about the performance that might be expected of them at university. Each point by which the ATAR cut-off for Year 12 entry is lowered might have only a relatively small effect (estimated at 0.74 percentage points in the OLS regression analyses) on the conditional mean WAFYM expected of such students; the effect on failure rate, however, is more dramatic and has significant implications for both the resourcing of university teaching and for the public funding of university places.

Policy implications for widening participation through alternative entry pathways

Our results should serve to allay concerns (see for example, Bagshaw & Ting, 2016; Hare, 2015) that universities will necessarily find themselves overwhelmed by students who are poorly prepared for

university study if they allow students with poor secondary-school results (i.e., low ATARs) to enter university. In the case of such students who enter university via the alternative entry-pathway of post-secondary education at a college of technical and further education, their first-year university results are, on average, better than those of students who enter directly from secondary school. Furthermore, the overall variance of their results is lower than that of post-secondary entrants. Although the likelihood of a TAFE-entry student performing exceptionally well is lower than that for a student entering directly from Year 12, a TAFE-entry student is also more likely to deliver a creditable first-year performance than a Year 12 entrant. On that basis, it would appear that universities that take TAFE-entry students run little risk of reputational damage and are in fact making a sound investment. In fact, our results suggest that when a university is faced with a choice between admitting a marginal Year 12 entry student and admitting a marginal TAFE entry student, it might be prudent to choose the TAFE entry student. This is a significant point given the relatively greater representation of socio-economically disadvantaged students among TAFE attendees (Department of Education, 1990), despite the fact that our data do not allow us to examine the socio-economic status of students who actually apply to enter university through the TAFE entry path.

Although one might ask why it is that TAFE-entry students deliver the profile of results that we have documented here, we have no direct evidence relating to the issue and must resort to speculation; nonetheless, the speculations give rise to questions to be answered through future research. One possibility is simply that good students who, through bad-luck or chance, performed badly in their final secondary-school examination get a second chance to demonstrate their ability when they go to a TAFE college. Another possibility is that by going to a TAFE college weaker students, for whom the ATAR was an accurate representation of their academic preparedness at the end of secondary school, gain additional time in which to develop and practise important skills such as advanced literacy and numeracy. Other possibilities, as we remark in O'Brien-Malone and Diamond (2015), relate to the roles that increased social maturity and enhanced organizational skills might play in determining university outcomes.

Implicit in the preceding discussion has been the assumption that the admission of students to university through alternative pathways does in fact “widen participation” in the sense of increasing the diversity of backgrounds of the university student body. Again, limitations of the data to which we had access prevent us from examining the question directly but evidence from New Zealand and the United Kingdom suggests that it does. Turner et al. (2012), for example, remarked that “evidence of this phenomenon [i.e., increased diversity as a result of the accessibility of alternative entry pathways] has been observed consistently across three successive cohorts of students” (p. 236). Similarly, Foster (2009) reported that

students' socio-economic backgrounds and early educational experience help to dictate routes into and pathways through HE. ... [S]tudents from some ethnic minority groupings e.g. students of Afro-Caribbean or African origin and / or lower socio-economic classes were more likely to be taking alternative routes into and pathways through HE. (p. 89)

Conclusions

Given the significant policy implications of the results, it is worthwhile to make explicit a caveat that has generally been omitted from other papers (e.g., Birch & Miller, 2005, 2006; Dobson & Skuja, 2005; Torenbeek, Jansen, & Hofman, 2010), namely that the results reflect events and policies, including university-admission and academic-grading policies, in play at a single Australian university during a particular time period. It remains to be seen whether similar relationships between admission pathway, ATAR, and first-year university performance obtain at other universities. Whether or not such relationships can be uncovered and the extent to which they will be found to be universal or, instead, strongly dependent on the particular time and particular university, will depend to a large extent on the readiness with which universities make the data, as well as their own analytically-based conclusions, available for analysis.

It would be an interesting exercise to examine the quantile regression fits to similar data obtained from a variety of higher education institutions. For each university individually, the quantile regression

results would help to move attention away from the problematic indicator of student mean-performance towards an examination of the likelihood of any given level of performance. No doubt there would be arguments about whether differences in the regression models of different universities were a consequence of differences in teaching quality, student ability, or severity of grading but in any event, the results would be likely to lead to a closer regard for institutional differences and similarities. They would also help to inform future endeavours to improve the diversity of the university student body.

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ATAR is a registered trademark of the Victorian Tertiary Admissions Centre.

Disclosure statement

No potential conflict of interest was reported by the authors.

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Appendix. A conceptual and technical description of the analytic methods

Quantile Regression Models

Quantile regression was developed in its modern form by Koenker and Bassett (1978) as a method for overcoming the sensitivity that OLS estimators have to outliers, and as a robust alternative to OLS regression with distributions that are long-tailed, heteroscedastic, or simply non-normal. In contrast to OLS regression, quantile regression models make no assumption about the distribution of errors. Quantile regression therefore admits the possibility that independent variable X affects not only the location of the conditional distribution of the predicted variable Y but also its scale and shape (Koenker & Hallock, 2001). Median regression is the most commonly encountered form of quantile regression and has similar advantages over OLS predictions of the conditional mean to the advantages that the median has over the mean as an indicator of central tendency. Of particular importance is that the median regression line is not “pulled from the centre” by the asymmetrical occurrence of extreme values. More generally, quantile regression is more flexible than OLS because it is not restricted to modelling a single conditional value and given enough data one can potentially model any conditional quantile, even in the tails of a distribution. Using quantile regression to analyse educational data allows the possibility of exploring factors that predict, explain, or help to describe, poor performance (the 0.05 quantile) or excellent performance (the 0.99 quantile) and not simply average performance.

Restricted cubic splines

At the turn of the nineteenth century, a spline was a “flexible strip of wood or hard rubber used by draftsmen in laying out broad sweeping curves, especially in railroad work” (Century Dictionary, 1891). For the computer (i.e., human calculator) of the early twentieth century, the advantage of a spline was that it could be moulded to permit a smooth curve to be drawn through a set of points without having to specify, or calculate, a functional form for the curve. Once drawn, the curve could be used to interpolate or, more hazardingly, extrapolate for the purposes of prediction. Software based cubic splines (Press, Teukolsky, Vetterling, & Flannery, 2007) now replace the strip of rubber but offer similar advantages over linear regression; it is unnecessary for an investigator to assume any specific relationship (and especially not one that is strictly linear) between the variables of interest. A refinement of the general cubic spline has been the development by Stone and Koo (Stone & Koo, 1985) of cubic splines that are restricted to being linear in the tails – analogous to the draftsman’s spline that has a straight portion at either end.

A restricted cubic spline (also referred to as a natural spline) is a piecewise polynomial with $k + 1$ segments joined at k “knots”, $t_1, \dots, t_k$, with

$$f(X) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_{k-1} X_{k-1}$$

where $X_1 = X$, and the $X_{j>1}$ represent a truncated power basis for the construction of the piecewise polynomial. For $j = 1, \dots, k - 2$

$$X_{j+1} = (X - t_j)_+^3 - (X - t_{k-1})_+^3 (t_k - t_j) / (t_k - t_{k-1}) + (X - t_k)_+^3 (t_{k-1} - t_j) / (t_k - t_{k-1}),$$

with the $()_+$ function defined as

$$(z)_+ = \begin{cases} z, & z > 0 \\ 0, & z \leq 0. \end{cases}$$

Notwithstanding a decision to introduce spline models, one can determine whether $f(X)$ is in fact linear in X – indicating that the model could be simplified with a straight-line fit – by testing

$$H_0: \beta_2 = \beta_3 = \dots = \beta_{k-1} = 0.$$

If the null hypothesis cannot be rejected, a straight-line fit should replace the cubic spline (Harrell, 2001).