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Fifteen Years of a PBRFS in New Zealand: Incentives and Outcomes

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Abstract

This paper examines the transformation of New Zealand universities following the introduction in 2003 of the Performance-Based Research Fund System (PBRFS), which assesses performance quality using a peer-review process, and allocates funds based on individual researcher performance. The analysis, based on a social accounting framework, utilises longitudinal researcher data available from the three full assessment rounds, in 2003, 2012 and 2018. The longitudinal data enable identification of entry, exit and quality transformation of researchers and their contribution to changes in university and discipline research quality. The dynamics are found to be closely related to the new incentives created by the assessment system. According to the quality metric used by the PBRFS, the research quality of NZ universities increased substantially over the period, although the rate of increase was much slower during the second period, 2012 to 2018, and considerable heterogeneity across universities and disciplines was revealed. Much of the improvement can be attributed to the high exit rate of lower-quality researchers. New entrants consistently reduced the average quality of all groups, reflecting the difficulty of recruiting high-quality researchers. Changes in the discipline composition of universities made a negligible contribution compared to improvements in the quality of the stock of researchers.

Key words: Performance-Based Research Funding Systems; policy evaluation; research quality; Social Accounting Framework.

JEL classifications: I2; I28.

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1. Introduction

The aim of this paper is to examine the transformation of New Zealand universities following the introduction in 2003 of the Performance-Based Research Fund System (PBRFS). So far, there have been three full assessment rounds, in 2003, 2012 and 2018.[1] The PBRFS was designed to unbundle the research component of Government funding of New Zealand tertiary education organisations, and allocate the research component based on research performance rather than the number of students.[2] The Tertiary Education Commission (TEC) explained the aims as follows: ‘The purpose of the ... [PBRFS] ... is to ensure that excellent research in the tertiary education sector is encouraged and rewarded. This means assessing the research performance of tertiary education organisations (TEOs) and then funding them based on their performance’.[3] A distinctive feature of the NZ system is that research performance is based on the peer-review evaluation of each individual researcher.[4] Funding to universities flows from the quality assessment of each researcher. Measures of average research quality for universities and discipline groups are constructed from the individual assessment.

Crucially, the introduction of this new system changed the incentives facing individuals, departments and universities. Not surprisingly, it has given rise to an extensive debate about the perceived consequences and merits, or otherwise, of the change. This debate is worldwide, in view of the widespread adoption of performance-based schemes for allocating research funding.[5] Much of the debate has been concerned with broad issues such as the possible effects on academic freedom, the diversion of energy away from teaching excellence, the introduction of a competitive rather than collegial atmosphere in universities, the discouragement of longer-term scholarly projects, the nature of the metric devised to measure research quality, and the high compliance costs.[6]

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[1] There was an incomplete round in 2006.
[2] Three measures are used to allocate Government funding to support research at universities and other tertiary education organisations. The largest component, the focus of this paper, is Quality Evaluation which comprised 60 per cent of the funds allocated following the 2003 and 2012 assessments and 55 per cent following the 2018 assessment. The other components are Research Degree Completions (25 per cent of the allocated funds) and External Research Income (15 per cent of the allocated funds following the 2003 and 2012 assessments and 20 per cent following the 2018 assessment).
[3] See The Tertiary Education Commission (2019, p. 11).
[4] The defining characteristics of a PBRFS are outlined by Hicks (2012). The NZ system meets these characteristics.
[5] Extensive discussions can be found in, for example, de Boer *et al.* (2015), Kolarz *et al.* (2019) and OECD (2010). Discussion possible adverse effects of the UK system is in Martin (2011).
[6] On the various metrics, see Wilsdon *et al.* (2015).

However, the present paper is concerned with an analysis of the incentives and the nature of the changes that have been induced by those incentives. As suggested by Checchi *et al.* (2019), a consensus has not yet been reached regarding the effects of the introduction of a PBRFS. Essentially, there are three broad ways by which a university can improve its quality of research. The change in average quality over a specified time period depends on the exits and entries of individuals (to and from other universities in NZ, or international movements), and the extent to which remaining individuals can improve their measured quality. A university can also influence its average quality by changing its discipline composition, by reducing the share of relatively poor-performing disciplines at the expense of higher-quality discipline groups. Of course, strong constraints are placed on the changes that can be made by university managers. This study examines these changes in detail. It has been made possible by access to a special dataset that contains anonymised longitudinal information about every researcher who participated in any assessment round from 2003 to 2018. These data include research quality scores, university and discipline affiliation, age, and full-time equivalent status. The data are not publicly available and were provided by the Tertiary Education Commission (TEC) following a confidentiality agreement.

One important question, that has attracted much attention in the literature, is concerned with whether observed changes can be attributed to the introduction of a PBRFS. It is sometimes suggested that universities have always striven to improve research quality, that academics are necessarily highly self-motivated, and that a competitive environment (both among researchers seeking promotion and universities wishing to attract students and high-quality academics) exists without the need for a formal evaluation process. Typically, no empirical measures of the metrics designed by PBRFSs exist until the formal evaluation process begins. Although attempts have been made to look for structural breaks in series of bibliometric measures, there is a low degree of concordance between such measures and the metrics used in PBRFSs.[7] The present study, by focussing on the precise nature of the incentives and the routes by which performance can be improved, is able informally to test a number of hypotheses relating to changes that can be attributed directly to the PBRFS.[8]

In discussing research quality here, the metric used by the NZ system is taken at face value, and hence the term 'high-quality researcher' relates specifically to the official quality measure

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[7]See, for example, Baccini and De Nicolao (2016), Aksnes and Taxt (2004), and Aksnes *et al.* (2019, pp. 6-7).

[8] Using a different approach, Woerlert and McKenzie (2018) found that Australian universities tended to replicate the national performance indicators used in the national PBRFS in their individual-level performance management frameworks for academic staff.

(described below). This is consistent with the aim of attempting to disentangle the precise incentives and the ways in which universities have been transformed over the fifteen-year period of operation of the PBRFS. This should not necessarily imply agreement with the metric: indeed, it has several unusual properties and no rationale has ever been provided by the TEC or the Department of Education.[9]

Section 2 explains the essential features of this system, its key metrics, and the longitudinal data used.[10] The incentives created by the introduction of the system are discussed in Section 3 together with some hypotheses regarding organisational changes. Section 4 explains how the data can be utilised to trace changes in researcher quality and the entry, exit and quality transformation of researchers, and how these contribute to changes in overall university research quality. Section 5 applies a decomposition method to identify the separate contribution of these components to changes in the research quality of individual universities and disciplines. This is extended in Section 7 to identify the contributions of changes in discipline composition. The approach is adapted in Section 8 to assess the possible sustainability of observed organisational changes and, hence, to assess the impact of the introduction of the PBRFS. Section 9 provides concluding comments.

2. The New Zealand PBRFS: measurement of research quality and data

The PBRFS assigns each researcher to a Quality Category (QC) by a complex peer-review process undertaken by a panel of experts in each research subject area. These QCs are used to allocate funding to universities, and are used to compute a quantitative performance score, referred to as an Average Quality Score (*AQS*) for each subject area and university. This section defines the *AQS*, and provides some descriptive statistics by university and discipline for each of the assessment rounds in 2003, 2012 and 2018.

For each researcher portfolio submitted, covering the previous six years, the QC is determined for each individual by a panel assigned to a subject area or group of subject areas.[11] There are

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[9] For a detailed analysis, see Buckle and Creedy (2019b).

[10] An earlier series of paper (Buckle and Creedy, 2019a, 2019b, 2020, and Buckle *et al.*, 2020) examined the changes over the period 2003 to 2012. The present paper covers the complete period 2003 to 2018 and the dataset contains additional information about researchers' characteristics, including full-time equivalent status, and transfers among universities and disciplines.

[11] The process begins by selected members of a Panel attaching a cardinal value to each of three aspects of research quality, and then forming a weighted sum of these values. However, these values undergo substantial revisions by the full panels. The weighted sum can vary from 0 to 700, and the QCs (A, B, C, R) are defined by a set of ranges. No rationale has ever been given for this process, which has unusual numerical properties and involves converting a cardinal score into a qualitative category, and then converting back into a quite different cardinal score which ignores variations within each category; see Buckle and Creedy (2019b) for details.

four QCs, indicated by A, B, C and R, where the highest category is A, and R indicates an absence of significant research outputs. Each individual is given a cardinal score depending on the letter grade: 10 for A; 6 for B; 2 for C; and 0 for R. The average quality score, *AQS*, for any group (university or discipline) is the (full-time equivalent) employment-weighted arithmetic mean score. At the end of each round, the TEC publishes a summary of the results and includes a variety of measures of average quality, depending on the choice of denominator; see The Tertiary Education Commission (2004, 2013, 2019).[12]

The dataset used here includes the QC assigned to every researcher who participated in each assessment round in 2003, 2012 and 2018. It also contains, for each researcher, an anonymous identifier, age, research subject area, university of employment, and employment status (in terms of full-time equivalent, FTE) including whether the researcher exited or entered the entire New Zealand university system between rounds or transferred to or from another NZ university.

Table 1 shows the number of FTE researchers by university, and for each of nine research discipline groups. The discipline groups were created by assigning the 42 TEC research subject areas to one of nine discipline groups.[13] The number of researchers assessed between the first two assessment rounds (2003 and 2012) fell by 4.3 per cent, but increased by 12.9 per cent in the following period (2012 to 2018). The total number of FTE researchers grew by 8 per cent over the 15 year period, but there are substantial variations among universities and discipline groups.[14] Among universities, Waikato and Massey researchers fell by about 19 per cent and 15 per cent respectively. In contrast, Victoria University of Wellington (VUW) and Auckland University of Technology (AUT) FTE researcher numbers grew by nearly 37 per cent and 31 per cent respectively, thereby increasing their shares. Among the discipline groups, the largest decline is of Education researchers: the number of FTEs fell by over 33 per cent, and its share fell by 4 per cent. There were also relatively large absolute and share declines in Humanities

[12] Two new categories C(NE) and R(NE) were introduced by the TEC for the 2012 and 2018 assessment rounds to signify if a researcher met the 'new and emerging' criteria. The score assigned by the TEC to R(NE) was 0 in 2012 and 2018, the same as in 2003. The score assigned by the TEC to C(NE) was 2 in 2012, the same as for C, and 4 in 2018 (The Tertiary Education Commission, 2019, p. 13). For the purposes of this paper the score assigned to C(NE) in 2018 is set equal to 2 to ensure consistency over time.

[13] The subject composition of each discipline group is explained in Buckle and Creedy (2020, Appendix 1). A new subject area (Pacific Research) was introduced in the 2018 assessment, which for present purposes is assigned to the Humanities discipline group.

[14] Comparison of the total portfolios submitted with total teaching and research staff at NZ universities indicates that this 8 per cent growth in total portfolios submitted was due to a rise of about 6 per cent of total teaching and research staff and a rise of about 2 per cent in the proportion of total teaching and research staff submitting a research portfolio. Using as a measure of 'research active' those individuals publishing at least one article, in whole or part, during a six-year period in an EconLit-listed journal, Anderson and Tressler (2014, p. 7) concluded that the proportion of research-active staff in New Zealand universities increased following the introduction of the PBRFS.

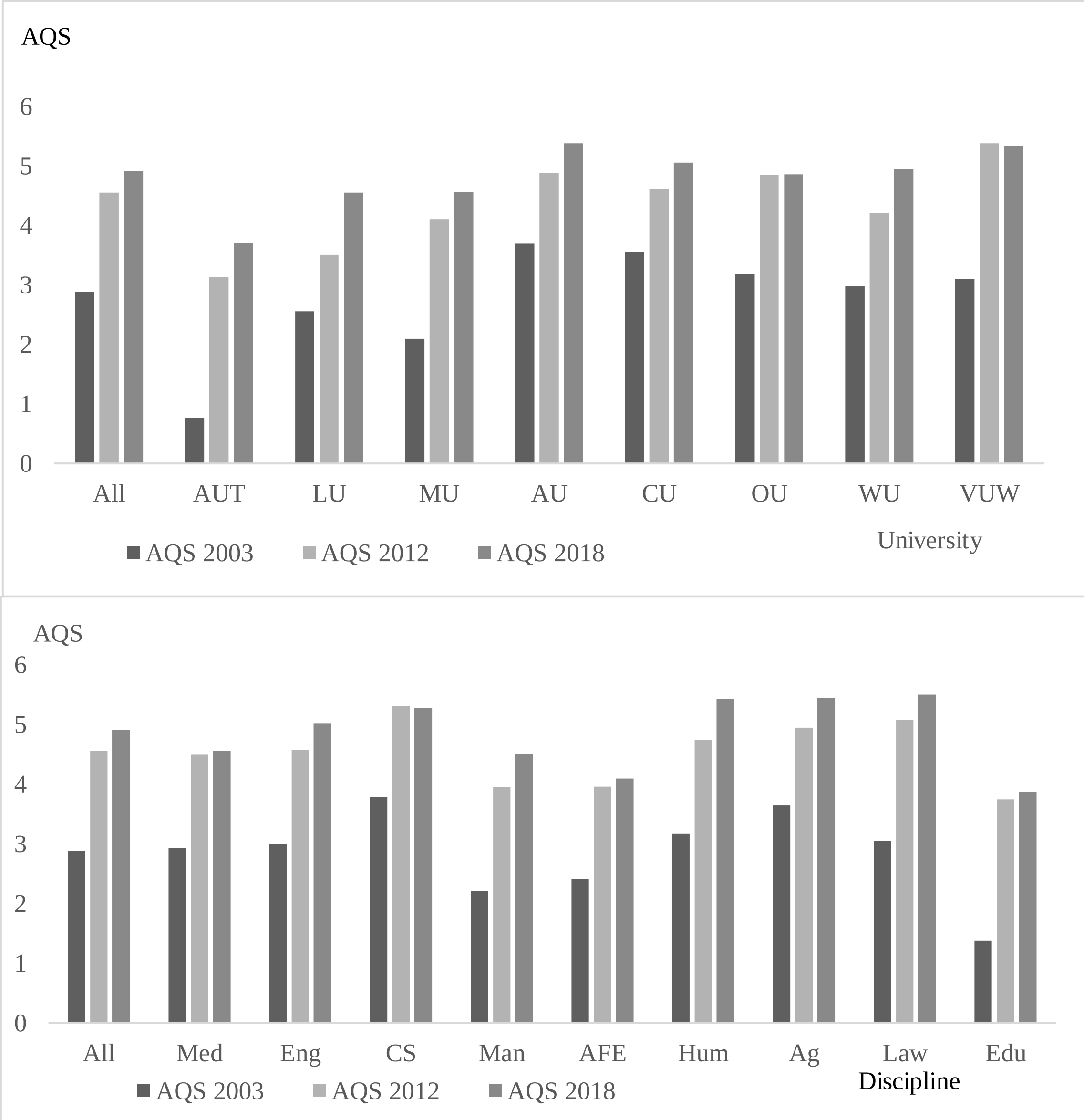
and Management researchers. In contrast, the numbers of Medicine, Engineering and Agriculture researchers increased by between 20 and 30 per cent.

Table 1. University researchers assessed each PBRFS round from 2003 to 2018

University / Discipline	Number of staff who submitted evidence portfolios (FTE) 2003	Change	2012	Change	2018	% Growth 2003-18	% Δ Share
AUT	566.74	-77.85	488.89	252.26	741.15	30.8	1.9
Lincoln	195.34	4.31	199.65	-17.52	182.13	-6.8	-0.4
Massey	1,225.88	-259.73	966.15	75.90	1,042.05	-15.0	-4.0
Auckland	1,541.86	86.80	1,628.66	146.07	1,774.73	15.1	1.5
Canterbury	640.35	1.73	642.08	-36.08	605.70	-5.4	-1.2
Otago	1,192.94	1.65	1,194.59	197.07	1,391.66	16.6	1.4
Waikato	535.98	-62.34	473.64	-39.17	434.47	-18.9	-2.0
VUW	632.04	25.00	657.04	225.65	882.69	36.7	2.8
Total	6,531.13	-280.43	6250.70	803.88	7054.58	+8.0	
Medicine	1,549.80	70.23	1620.03	339.30	1,959.33	26.4	4.0
Engineering	863.78	7.16	870.94	189.44	1,060.38	22.8	1.8
Core science	510.63	-39.88	470.75	66.69	537.44	5.3	-0.2
Management	454.64	-65.53	389.11	31.38	420.49	-7.5	-1.0
Acc Fin Eco	345.38	-27.14	318.24	32.04	350.28	1.4	-0.3
Humanities	1,385.56	-108.23	1,277.33	127.77	1,405.10	1.4	-1.3
Agriculture	519.16	71.63	590.79	83.74	674.53	29.9	1.6
Law	215.65	-27.36	188.29	2.22	190.51	-11.7	-0.6
Education	686.53	-161.31	525.22	-68.70	456.52	-33.5	-4.0
Total	6,531.13	-280.43	6250.70	803.88	7054.58	8.0	

The *AQS*s for each university and discipline group are shown in Figure 1. For the entire university system, there was a rise in average research quality, as measured by the *AQS*. The FTE-weighted average *AQS* increased from 2.88 to 4.55 between 2003 and 2012, a rise of nearly 60 per cent, and an annual compound growth rate of 5.2 per cent. For the six-year period 2012 to 2018 the weighted average *AQS* increased to 4.91, a rise of about 8 per cent, and a much lower annual compound growth rate of about 1.3 per cent. This broad pattern, of higher initial growth in research quality followed by slower subsequent growth, holds for all but one university (Lincoln) and all disciplines, suggesting that if the initial growth can be, at least in part, attributed to the introduction of the PBRFS, the impact appears to be diminishing. The suggestion of a fading effect is consistent with the findings of several other studies; see the review by Checchi *et al*. (2019).

Figure 1. University and discipline AQSs in 2003, 2012 and 2018.



Notes: **Universities**: AUT = Auckland University of Technology; MU = Massey University; LU = Lincoln University: AU = Auckland University; CU = Canterbury University; OU = Otago University; WU = Waikato University; VUW = Victoria University of Wellington. **Disciplines**: Med = Medicine, Eng = Engineering; CS = Core Science; Man = Management; AFE = Accounting, Finance and Economics; Hum = Humanities; Ag = Agriculture; Law = Law; Edu = Education. The *AQS* values for each university and discipline are reported in Table 6.

3. Effects on university incentives of the New Zealand PBRFS

The PBRFS introduced new financial incentives for the management of New Zealand universities, by directly aligning Government funding of research with the perceived quality of researchers. The new funding system directly linked a dollar amount of research funding to each university per based on the Quality Category of each individual researcher. It also introduced new reputational incentives and new information about the relative research quality of universities and disciplines. The results of the first assessment round in 2003 provided all universities, for the first time, with publicly available information on what was regarded as high-quality research, and how this was distributed among universities and disciplines.[15] It created a new knowledge environment and financial incentives that could be expected to give rise to a complex transition process. This section considers the precise ways in which those incentives may be expected to generate responses relating to the exit, entry, and transformation of researchers.

Importantly, the incentives vary among universities depending on their initial *AQS*. For example, the proportional increase in the *AQS* of a university, for example from recruiting a new researcher, depends on the existing AQS, as well as the quality of the entrant. Clearly, if a university has an *AQS* greater than 2, its *AQS* would fall as a result of hiring one more C-type researcher: it would need to recruit at least at level B, or reduce the number of R-type people and substitute them with a new C or higher-quality researcher. There are sharply decreasing returns, in terms of the impact on *AQS*, from hiring A and B researchers. Furthermore, the gain from the exit of R-type researchers depends on their existing number, as a proportion of the total number of (FTE) employees. These properties suggest that university responses to the introduction of the New Zealand PBRFS are likely to vary depending on their initial situation.

Faced with a strong incentive to improve the research quality of staff, several organisational responses are possible, each with different costs and constraints. There are also institutional constraints, relating to hiring and firing, the nature of contracts, the degree of wage flexibility, the allocation of university funds among departments, the concentration of power to make hiring and firing decisions, and so on. These features make the construction of a formal dynamic university model extremely difficult. However, it is useful to consider the broad characteristics that may be expected to follow from an objective of increasing the *AQS*. The following considers the incentives regarding exits, entrants, and quality transformations in turn. The discussion, though informal, motivates the empirical analysis that follows.

3.1 Exits

The rate of exit of Rs is likely to be higher than for other categories for 2003 to 2012, given that no funding is available through the PBRFS. However, given the multiple outputs of a university, involving teaching and external engagement as well as research, an appropriate staffing balance

[15] Detailed information was provided by the publication of results from the first assessment in 2003 in The Tertiary Education Commission (2004).

is obviously required. Nevertheless, organisational responses which reduced the proportion of R researchers would enhance all university and discipline *AQSs*.

Similarly, the rate of exit of Cs is likely to be higher than that of As and Bs. In 2003, the AQS for AUT and Massey, and for the Education discipline, was below the score (of 2) attached to Cs. But, by 2012 the *AQS* for all universities and disciplines exceeded 2. The option of reducing the proportion of C's was consistent with increasing the *AQS* for all universities and disciplines during the later period 2012 to 2018.

3.2 Entrants

The entry rate of As, Bs and Cs for 2003 to 2012 is expected to be higher than that of Rs. A low rate of recruitment of Rs is expected, although this is unlikely to fall to zero. The possibility of substituting of Cs for Rs, coupled with the cost of Cs compared to As and Bs in the same discipline, implies that a high rate of recruitment of Cs remains likely in the 2003 to 2012 period (even though, as mentioned above, the recruitment of Cs alone would reduce the AQS of most universities).

Furthermore, the entry rate of As and Bs during 2012 to 2018 is likely to be higher than during 2003 to 2012. The higher score for As and Bs compared with Cs, and an increase in the *AQS* beyond two for most universities by 2012, implies that a rise in the entry rate for As and Bs, compared with that for Cs, is likely for the 2012 to 2018 period.

3.3 Quality Transformations

The rate of upward transformation of Bs and Cs to As is likely to be higher than of Rs. The time and resources required to convert an R researcher into an A quality researcher are likely to be much greater than those needed to convert a B or C researcher to an A. Similarly, the transformation rate of Bs to As is expected to be higher than for Cs to As.

Furthermore, the proportion of all A and B researchers in 2018 is likely to be higher than in 2003. As discussed above, there is likely to be a higher proportion of researchers in QC categories with QC scores above the *AQS* in 2012. The all-universities *AQS* in 2012 was 4.55, and hence it is expected that the sum of A and B researchers as a proportion of total researchers increased by 2018 (compared to 2003 and 2012).

In addition, significant differences among disciplines in their transitions can arise from differences in research methods, funding opportunities, alternative labour market opportunities, and the opportunity costs of careers in academia and research. Individual characteristics (age, experience, gender and personal preferences for research), institutional characteristics (performance management, commercial orientation of research, the presence of PhD programmes, and institutional mission and priorities), research methods (collaboration, team research, joint authorship), and the availability of contestable research funding, all influence research productivity and vary among disciplines.

For example, Wanner *et al*. (1981) found that discipline was an important influence on the research environment and type of research output. Shin and Cummings (2010) concluded that staff collaboration, time spent on research, institutional goal-orientation and institutional mission influenced academic publishing, and differed by academic discipline. Similarly, in an assessment of the influences on the research productivity of Hong Kong academics, Jung (2012) found that the influence of individual and institutional factors on self-reported research output differed significantly between natural sciences, engineering, and medical science disciplines and the humanities, social sciences, and business disciplines. Sabharwal (2013) found that research productivity was associated with discipline and career stage.

Rates of entry and exit are also likely to differ among disciplines. Xu (2008) found that substantial and systematic variations exist among different disciplines with respect to the main factors that determine staff turnover. Salaries and the presence of alternative career opportunities influence mobility, and the ability of institutions to recruit research staff in the education field; see for example Ehrenberg *et al.* (1991).

4. The Social Accounting Framework

The discussion of incentives, in the previous section, highlighted their likely role in influencing patterns of entry, exit and quality transitions of researchers. The primary tool for the analysis of such changes is the social accounting framework, with its core component, the transition matrix, showing the movements of individuals (or full-time-equivalents) between discrete categories from one period to another.[16] The transition matrix of flows reveals the predominant changes that lie behind the *AQS* increases from one assessment round to another. This section focusses on the dynamics for the entire university system. Section 5 considers the dynamics for each university and discipline.

[16] It seems that the first papers applying the social accounting framework to the education sector were by Stone (1965, 1966). This work involved the application of input-output analysis and Markov chain methods for the purpose of calculating resources, including demographic, required to achieve specified educational outputs.

The transitions for all universities combined are shown, for movements between 2003 and 2012, and 2012 to 2018, in Table 2. The flows are from rows to columns, and the transition proportions (the flows as a proportion of the initial total number in each category) are given in parentheses immediately beneath the frequencies. The number of researchers remaining in the same QC (the diagonal entries in the matrix) are highlighted in bold. Table 2 reveals that, consistent with section 3.1, the largest exit rate during the period 2003 to 2012, at just over 70 per cent, is of those assessed as R-quality researchers in 2003.

Table 2 shows, again consistent with section 3.2, that the exit rate of Cs during the period 2012 to 2018, at just over 39 per cent, was higher than for As (27.2 per cent) and Bs (29.9 per cent). The total number of exits of Cs was just over 46 per cent of total exits. A higher entry rate for As, Bs, and Cs in 2003 to 2012 compared to that for Rs, shown Table 2, is consistent with the discussion in section 3.2. The highest entry rate is for Cs, at nearly 52 per cent. This is consistent with the change in reputational and financial incentives faced by universities and the need to substitute new researchers for the high rate of exit of Rs that occurred during 2003 to 2012. However, there is no evidence of a tendency for the entry rate of As and Bs to rise during 2012 to 2018 compared to the entry rate for Cs, which remained the dominant source of new entrants during 2012 to 2018.[17] This may well reflect the relative scarcity of higher-quality researchers. New Zealand and Australia have relatively small academic labour markets, and universities draw heavily on academics from northern hemisphere markets. The costs of relocation and salary differentials make the recruitment of higher-quality researchers difficult. This is likely to be a factor in contributing to the slower rate of growth of *AQS*s from 2012 to 2018 compared to the earlier period. Boyle (2008) demonstrated that differences in labour market opportunities affected the relative research performance of academic disciplines.

The quality transformation rates of B, C and R into A researchers in both periods is consistent with the incentives discussed in section 3.3. The transformation rate for Bs to As was about 18 per cent in both periods; for Cs it was close to 3 per cent in 2003 to 2012 and 2 per cent in 2012 to 2018. For Rs, the transformation rate was almost zero in 2003 to 2012 and was zero in 2012

[17] Additional QC categories were introduced in 2006 to deal with relatively new researchers called 'new and emerging' (NE) for researchers with C and R quality categories, and for revenue purposes the $G_h = 4$ for C(NE) since 2018. Buckle and Creedy (2019a) evaluated whether this distinction affected the probability of upward transformation, and therefore whether this distinction influenced recruitment rates of NE category Cs and Rs. They found the distinction in the case of Cs appears to have little value. But in the case of R researchers, those who were NE do appear in general to have experienced more upward movement than other Rs. This supports the suggestion that the PBRF encouraged more careful selection of entry-level researchers.

to 2018. The same pattern is evident for the rates of quality transformation of Cs and Rs to Bs and, as expected, the transformation rate of Cs and Rs increases as the 'target' QC is reduced.

Table 2. Matrix of flows: all universities 2003 to 2012 and 2012 to 2018

	Category in 2012					
Category in 2003	A	B	C	R	Exits	Total
A	**224.78** (0.531)	64.13 (0.151)	2 (0.005)	0	132.64 (0.313)	423.55
B	301.13 (0.178)	**630.93** (0.373)	144.57 (0.086)	1.66 (0.001)	610.87 (0.362)	1689.16
C	64.17 (0.029)	562.68 (0.254)	**492.86** (0.223)	25.21 (0.011)	1067.31 (0.483)	2212.23
R	7.47 (0.003)	134.85 (0.061)	412.20 (0.187)	**102.35** (0.046)	1549.32 (0.702)	2206.19
Entrants	234.58 (0.076)	1082.83 (0.352)	1587.53 (0.515)	174.77 (0.057)		3079.71
Total	832.13	2475.42	2639.16	303.99	3360.14	9610.84
	Category in 2018					
Category in 2012	A	B	C	R	Exits	Total
A	**496.75** (0.600)	104.29 (0.125)	4.36 (0.005)	0	226.73 (0.272)	832.13
B	445.35 (0.180)	**1090.38** (0.440)	195.31 (0.079)	3.70 (0.002)	740.68 (0.299)	2475.42
C	48.31 (0.018)	773.23 (0.293)	**752.53** (0.285)	30.91 (0.012)	1034.18 (0.392)	2639.16
R	0	23.60 (0.078)	97.57 (0.321)	**18.96** (0.062)	163.86 (0.539)	303.99
Entrants	168.21 (0.057)	902.70 (0.304)	1769.08 (0.596)	129.34 (0.043)		2969.33
Total	1158.62	2894.20	2818.85	182.91	2165.45	9220.03

Note: The sum of category A, B, C, R portfolios in the 'Total' rows and columns in each table equal the respective 2003, 2012 and 2018 portfolios totals in Table 1.

The patterns of change suggested by the hypotheses discussed above suggest a difference in the observed frequencies between the two periods, as suggested in sections 3.1 to 3.3. The statistical significance of the difference is confirmed by the χ^2 statistic, calculated by comparing the frequency distribution observed for 2012 to 2018 (Table 2) with an expected frequency distribution based on the observed frequencies for 2003 to 2012. An adjustment was made to allow for the fact that the 2003 to 2012 frequency distribution is for a nine-year period, whereas

2012 to 2018 is a six-year period.[18] The χ^2 statistic is equal to 992, which compares with the critical value (for a type I error of 0.01, and for 16 degrees of freedom) of 32.00, confirming a highly significantly different pattern of transition dynamics during the second period.[19] The main sources of the difference are: a higher exit rate for all grades; a higher proportion of entrants of Cs and Rs; a tendency for a higher upward transformation rate for Bs, Cs and Rs; and a smaller proportion remaining in the same QC during 2012 to 2018.

Table 3 summarises the changes in the distribution of QCs between successive assessment rounds. The number of R-graded researchers in 2003 as a proportion of total 2003 researchers was just under 34 per cent. The rate of exit of Rs between 2003 and 2012 was so large and the rate of recruitment or entrants of Rs so low, that by 2012 the proportion of Rs to total researchers was only about 5 per cent. The low stock of Rs in 2012, coupled with a continued suppressed rate of R entrants between 2012 and 2018, meant the proportion of Rs continued to decline and was less than 3 per cent by 2018. Nevertheless, although the number of R researchers had fallen substantially, the exit rate of R-researchers over the 2012 to 2018 period remained high, at 54 per cent.

Table 3. Exits, entrants and quality transformations

QC	2003 P/folios	Exits	Entrants	QTs	2012 P/folios	Exits	Entrants	QTs	2018 P/folios
A	423.55 (0.065)	132.63 (0.0.039)	234.58 (0.076)	306.64	832.13 (0.133)	226.73 (0.105)	168.21 (0.057)	385.01	1158.62 (0.164)
B	1689.16 (0.259)	610.87 (0.182)	1082.83 (0.352)	314.30	2475.42 (0.396)	740.68 (0.342)	902.70 (0.304)	256.76	2894.20 (0.410)
C	2212.23 (0.339)	1067.31 (0.318)	1587.53 (0.516)	-93.29	2639.16 (0.422)	1034.18 (0.478)	1769.08 (0.596)	-555.21	2818.85 (0.400)
R	2206.19 (0.338)	1549.32 (0.461)	174.77 (0.056)	-527.45	303.99 (0.048)	163.86 (0.075)	129.34 ((0.044)	-86.56	182.91 (0.026)
Totals	6531.13	3360.14	3079.71	0	6250.70	2165.45	2969.33	0	7054.58

Notes: The P/folios columns show the number of FTE-weighted A, B, C and R portfolios submitted in each round. QTs refers QC transformations and summarise the net impact of QC transformations (upward or downward of researcher QCs) for the researchers who remained within the system, by QC.

[18] The 2003 to 2012 frequency distribution is for the nine-year period 2003-2012 whereas 2012 to 2018 is a six-year period. Accordingly, the expected frequencies were derived by adjusting the 2003 to 2012 frequencies, assuming a constant annual rate of quality transformation, exit and entry, and reducing the observations in those cells and increasing those on the diagonal accordingly, for a hypothetical six-year period.

[19] The χ^2 statistic = 315 when expected 2012 to 2018 frequencies are based on actual 2003 to 2012 frequencies.

There was a rise in the proportion of As and Bs in both periods, consistent with the incentives discussed in section 3.2. Table 3 shows that the proportion of A-quality researchers increased by a factor of 2.5 between 2003 and 2018: from 6.5 per cent in 2003 to 13.3 per cent in 2012 to 16.4 per cent in 2018. The proportion of Bs increased by a factor of 1.5: from 25.9 per cent in 2003 to 39.6 per cent in 2012 and to 41 per cent in 2018. While changes in exit and entrance rates are part of the explanation, an important part of the explanation is also the rate of transformation of Cs to Bs and Bs to As.

5. Dynamics of individual universities and disciplines

The longitudinal data, as well as identifying the university affiliation and discipline of each person, indicate whether a researcher exited the university system or transferred to another New Zealand university. For the entire university system, transferring movements net out and therefore are not recorded as exits or entrants in Table 2. But for individual universities, they are part of the larger pool of researchers from which they can recruit, or lose, staff. These transfers could be an important source of quality change for a university and therefore could affect changes in *AQS*s between assessment rounds. There may also be researchers who have transferred from one discipline group to another. Therefore, in addition to rates of quality transformation of researchers who remain with the same university and discipline group, and the rates of researcher entry into and exit from the entire university system covered by the PBRFS, it is necessary to identify the effect of transfers between universities and disciplines, referred to as 'Transfers In' and 'Transfers Out'.

5.1 Individual universities

This subsection examines the extent of heterogeneity among universities (for all discipline groups combined) in their researcher dynamics. For example, it is of interest to consider how transition dynamics of universities with larger improvements in their *AQS* compares with those showing relatively little improvement, and to assess whether the dynamics of those universities with the largest improvement are consistent with the changes in the incentive structure brought about by the PBRFS, as discussed in section 3.

Table 4 provides information about how the flows of FTE researchers, from 2003 to 2012 and from 2012 to 2018, influenced the stocks of researchers in each QC in 2012 and in 2018. In addition to transformations of researchers who remain within the same university, and the exits and new entrants to a university from outside the university system, the flows in these tables show transfers to or from other universities. The corresponding transition proportions are easily obtained from the table and are not shown here in view of space constraints.

Table 4. Matrix of flows: universities 2003 to 2012 and 2012 to 2018

	Transitions 2003 to 2012						Transitions 2012 to 2018					
	A	B	C	R	T/Out	Exits	A	B	C	R	T/Out	Exits
AUT			χ^2=98.7						χ^2=77.76			
A	**2**	2	0	0	1	0	**9.5**	2.2	0	0	0	7.46
B	3	**18**	1	0	0	9	12.4	**68.41**	10	0	5.2	36.09
C	2	24.28	**21.59**	2	3.5	46.5	5.8	76.8	**89.45**	5.57	5	95.59
R	0	10.7	70.97	**19.84**	3	326.36	0	7	20.63	**6.48**	0	25.31
T/In	6.6	20	9.82	2.45			7	19.55	3.73	0		
Entrants	5.56	57.12	174.83	35.13			12.8	77.67	266.29	39.87		
Lincoln			χ^2=69.76						χ^2=28.91			
A	**5**	0.2	0	0	0	1.8	**10**	3.2	0	0	1	4
B	6	**13.7**	6	0.66	3.93	11.07	6.6	**23.9**	3	0	4	14.2
C	2	18.3	**27.1**	1.5	3	38.8	1	27	**22.98**	0	2	51.22
R	0	0	7.2	**9**	1.63	38.45	0	2	5.8	**0**	0	17.75
T/In	0	1.3	1.6	0			2	2	1.63	0.8		
Entrants	5.2	18.2	62.3	14.39			2.4	16.6	46.42	4.8		
Massey			χ^2=32.96						χ^2=34.67			
A	**18.17**	5	0	0	6.46	11.84	**53.1**	13.65	0	0	4.32	24.58
B	27.5	**70.26**	22.2	0	14.02	81.13	40.48	**140.1**	35.66	0	19.93	105.52
C	11	82.67	**112.68**	4.66	12.85	207.74	4.5	126.8	**153.97**	5	12.11	179.9
R	2	23.5	78.94	**18.1**	10.71	404.45	0	3.6	15.52	**1.9**	1.8	23.71
T/In	8	13.9	7.7	0			5	9	5.89	0		
Entrants	28.98	146.36	260.76	23.77			27.99	126.46	252.87	20.56		
Auckland			χ^2=24.65						χ^2=37.26			
A	**79.34**	14.11	1	0	10.13	50.82	**185.96**	29.04	1.96	0	4.44	67.21
B	103.32	**166.3**	36.8	0	24.48	184.82	134.95	**265.35**	48.23	0	12.8	174.3
C	16.86	127.35	**94.24**	6.3	22.91	236.49	17.19	186.09	**150.37**	7.09	20.5	250.57
R	2	20.63	72.63	**17.76**	8.9	244.65	0	6	20.15	**2.98**	1.8	41.68
T/In	14.86	21.7	4.8	0			9.07	23.56	3.64	0		
Entrants	72.23	285.52	422.34	48.55			43.47	223.59	395.55	20.49		
Canterbury			χ^2=49.6						χ^2=37			
A	**18.81**	7.5	1	0	3.7	23.03	**43.1**	8	0	0	7.75	21.79
B	29.48	**67.08**	9	0	8.46	93.32	40.4	**95.95**	20.56	0	7.2	105.69
C	4	52.21	**44.2**	0	6.9	137.52	3	68.46	**67.1**	3.3	4.63	120.13
R	0	10.11	41.2	**8.97**	2.9	70.96	0	0	7	**3**	0	15.02
T/In	10	10.66	4.16	0			5	7.73	2	0		
Entrants	18.35	122.24	167.06	16.05			14.06	76.24	137.86	2.94		

Otago			χ^2=42.08						χ^2=17.43			
A	**42.75**	15.15	0	0	7	25.21	**102.19**	25.86	1.4	0	4.6	45.51
B	66.27	**138.25**	32.52	1	8.83	96.82	93.21	**221.63**	39.28	0	9.23	140.76
C	10.41	97.46	**98.35**	1	11.16	196.76	4.75	137.32	**145.27**	4.95	9.1	183.18
R	1.27	22.15	52.73	**13.22**	2.8	251.83	0	1	10.82	**2**	0	12.53
T/In	7.61	16.11	6.23	0			2	9.62	2.28	0		
Entrants	51.25	214.99	294.74	11.13			26.52	160.26	374.24	27.06		
								χ^2=31.01				
Waikato			χ^2=61.79									
A	**10**	10.77	0	0	2.8	8.98	**16.22**	2.5	0	0	2	18
B	11.25	**49.03**	20	0	11.2	58.37	27.47	**82.47**	11.98	1	7.03	70.92
C	3	45.94	**50.12**	4.3	11.45	72.3	1.2	50.21	**49.78**	3	4.33	92.52
R	0	8.1	44.38	**12.46**	1	100.53	0	2	10.55	**0**	0	20.46
T/In	2	10.42	1.82	0			5	6.81	0	0		
Entrants	12.47	76.61	84.72	16.25			10.37	59.06	92.85	2		
VUW			χ^2=103.78						χ^2=57.48			
A	**19.82**	6.2	0	0	1	10.96	**53.31**	16.1	1	0	3	38.18
B	32.7	**61.83**	9	0	5.2	76.34	69.89	**144.13**	24.6	2.7	5	93.2
C	5.4	66.94	**27.03**	4	4.26	131.2	5.87	64.05	**50.44**	2	7	61.07
R	2	23.05	29.62	**2**	1.4	112.09	0	0	7.1	**1**	0	7.4
T/In	11.13	19.71	4	0			13.25	12.41	6	0.8		
Entrants	40.54	161.79	120.78	9.5			30.6	162.82	203	11.62		

Notes: 'T/In' refers to transfers into the university from another NZ university. 'T/Out' refers to transfers from the university to another NZ university. 'Exits' refers to researchers who exited the NZ university system, and 'Entrants' refers to researchers entering the university from outside the NZ university system.

The question considered here is whether the dynamics differ significantly among universities during both periods. First, consider whether individual universities differ from the pattern revealed by all universities combined. It is possible to calculate, for each university, the flows over the respective period which would result from applying the transition proportions and exit rates for all universities. Using these hypothetical flows as 'expected' values, a χ^2 test can be carried out. The resulting values are reported in each case on the same line as the university name. The appropriate χ^2 values, for type I errors of 0.01, 0.05 and 0.10 (for 25 degrees of freedom) are 44.31, 37.65, and 34.38 respectively.

There are two universities whose transitions do not differ significantly from those of all universities combined during 2003 to 2012: Massey and Auckland (Otago is not significantly different at the 0.01 level, but is for the 0.05 critical value). The university with the largest χ^2 value is VUW, with 103.78: this had the highest *AQS* in 2012 and the highest growth rate among the group of five universities (Auckland, Canterbury, Otago, Waikato, VUW) with the higher initial *AQS* values. The next-highest χ^2 value is for AUT with 98.7: this university had the lowest initial *AQS* and the highest percentage change over the period. While AUT and VUW differ most from the overall pattern, they also differ from each other considerably: comparing VUW with AUT (by computing expected frequencies by applying VUW transition and exit rates to the initial AUT stocks) a χ^2 value of 354.02 is obtained. The lower-ranked universities also differ significantly from each other: comparing Lincoln with AUT and Massey give chi-square values of 60.46 and 61.52 respectively. There is clearly considerable heterogeneity of transition dynamics among the universities during 2003 to 2012.

Importantly, the universities differ from each other in ways that are consistent with the new incentive structure introduced by the PBRFS. Thus AUT, with an initial low *AQS* of 0.77 in 2003, recruited a higher number of Cs and fewer As and Bs than predicted by the transitions of all universities combined. AUT also recruited Rs at a relatively higher rate. Auckland, Otago and VUW, which had much higher initial *AQS* scores, recruited fewer Cs and many more As and Bs than predicted using the transition proportions for all universities. Interestingly, there was a tendency for those universities with initial relatively high *AQS*s also to have higher rates of transformation or conversion of their initial stock of researchers to higher QCs than for those universities having lower initial *AQS*s. This is consistent with the discussion in section 3, which identified institutional factors such as goal orientation and institutional mission as having an influence on research performance (Shin and Cummings, 2010; Jung, 2012).

For 2012 to 2018 there are only two universities, AUT and VUW, whose dynamics differ significantly (at the 0.05 level of significance) from those of all universities combined, and the range of estimated χ^2 values is smaller. In terms of their dynamics, universities therefore became less heterogeneous during the second period. Nevertheless, as in the earlier period, there are remaining differences in the patterns of flows that are consistent with the incentive structures introduced by the PBRFS. For instance, the three universities with relatively low *AQS*s in 2012 (AUT, Lincoln, Massey) had lower recruitment rates of A and B researchers compared with the average for all universities, and recruited Cs and Rs at rates above the average. In contrast, universities with higher *AQS*s in 2012 recruited As and Bs at higher rates, and Cs and Rs at lower rates. This is clear, for example, for Auckland, Canterbury, Waikato and VUW. The tendency for those universities with initially relatively high *AQS*s to have higher rates of transformation or conversion of their existing stock of researchers to higher QCs than for those with lower initial *AQS*s scores persisted in the second period.

5.2 Individual disciplines

The dynamics of the various discipline groups (for all universities combined) are shown in Table 5. This reveals greater diversity of transition rates than among universities. During 2003 to 2012 only one discipline group, Management, had transition rates that do not differ significantly from those of all disciplines combined. The discipline with the largest χ^2 value is Education, with 108.52: this group had the lowest *AQS* in 2003, the largest change in total researchers, and the highest growth rate of *AQS* during the period.

Over the period 2012 to 2018, three disciplines (Management, Core Science and Engineering) had transition dynamics not significantly different from those for all disciplines combined. Nevertheless, there remained more diversity in discipline transition behaviour than among universities. Persistence of differences in transition dynamics is consistent with previous research, discussed in section 3, showing that turnover rates and research performances differ among disciplines, and these differences are influenced by the availability of alternative career and market opportunities (Ehrenberg, *et al.*, 1991; Xu, 2008; Boyle, 2008).

Table 5. Matrix of flows: disciplines 2003 to 2012 and 2012 to 2018

	Transitions 2003 to 2012						Transitions 2012 to 2018					
	A	B	C	R	T/Out	Exits	A	B	C	R	T/Out	Exits
Medicine			*χ^2=62.69*						*χ^2=55.55*			
A	**68.16**	13.5	0	0	2	16.82	**148.37**	24.61	0	0	4.94	53.88
B	86.76	**149.06**	28.06	0	16.47	131.89	104.24	**256.16**	54.73	1	15.36	154.97
C	14.31	131.9	**97.08**	2.55	16.46	268.2	6.63	175.44	**207.85**	6.94	35.34	287.19
R	0.57	26.46	71.72	**11.45**	11.5	384.88	0	5	25.32	**5.66**	2.8	43.6
T/In	3.74	18.45	20.41	2.61			7	11.7	10.67	1.2		
Entrants	58.26	247.09	502.12	65.77			37.94	202.13	615.28	51.46		
Engineering			*χ^2=49.33*						*χ^2=21.64*			
A	**33.66**	11.97	0	0	1.6	17.34	**69.79**	10.4	0	0	2	23.82
B	27	**85.62**	23.02	1	5	84.18	66.41	**144.11**	27.61	0	9.61	112.19
C	10	52.67	**68.47**	2	13.74	150.26	8	120.93	**86.97**	2	16.12	147.84
R	2	16.35	25.4	**7.8**	7	217.7	0	2	9.53	**1**	0.81	9.8
T/In	8.75	15.13	17.9	0			5.01	8	11.15	0		
Entrants	24.6	178.19	247.07	12.34			26.34	170.85	274.66	15.62		
Core Science			*χ^2=55.02*						*χ^2=17.43*			
A	**28.49**	7.72	0	0	2	17.19	**56.76**	12.2	0.4	0	2	27.18
B	33.71	**54.86**	16.73	0	10.8	54.19	31.55	**89.68**	13.2	0	5.2	56.35
C	2	32.86	**27.93**	1.3	8.5	106.25	4	39.3	**40.68**	1	10	74.95
R	0	1	9.72	**2**	1.53	91.85	0	0	2.5	**0**	0	3.8
T/In	7	5.5	12.22	0			5	4.65	1	1		
Entrants	27.34	94.04	103.33	3			12.51	79.61	136.4	6		

Management			*χ²=25.76*						*χ²=33.7*			
A	**6.46**	4	0	0	0.39	7.15	**12**	4.21	0	0	0	9.32
B	6	**33.9**	8.65	0	2.5	34.9	14.42	**68.16**	14.18	1	6	45.74
C	2	38.6	**40.51**	2	5	67.44	0.85	53.42	**52.12**	5	9.3	70.79
R	0.7	14.41	36.39	**9**	9.5	125.14	0	3	4	**2**	2	11.5
T/In	0	8.9	11.6	0.5			0	16	7	2		
Entrants	10.37	49.69	94.43	11			10.06	54.42	86.27	10.38		
Acc Fin Eco			*χ²=49.31*						*χ²=46.63*			
A	**7**	0	0	0	0	7	**16.7**	6.24	1	0	1	8.71
B	5.2	**32.22**	8.3	0.66	4.4	30.47	6.59	**51.06**	7.7	0	2	36.77
C	2	12.3	**21.47**	4	7.9	54.31	0	35.55	**57.91**	3	2	51.21
R	0	5.5	30.85	**10**	2.2	99.6	0	3	8.8	**3**	1	15
T/In	1	2	3	2			0	4.3	7	0		
Entrants	18.45	52.1	86.05	14.14			2.28	39.22	87.93	9		
Humanities			*χ²=72.57*						*χ²=57.32*			
A	**32.75**	13.4	1	0	1.2	39.73	**93.1**	24.54	0	0	1	42.45
B	62.31	**139.93**	35.29	0	10	168.33	107.09	**243.16**	37	0	14.5	169.27
C	11.5	133	**121.79**	6.41	14.66	218.89	9.79	170.4	**115.1**	3.37	17.25	193.58
R	2	22	69.14	**4.91**	28.32	249	0	4	10.6	**0**	1.22	19.91
T/In	3.8	21.15	15.73	3.46			14.98	30.93	18.78	1		
Entrants	48.73	241.54	266.54	20.95			40.82	207.94	261.05	11.45		
Agriculture			*53.45*						*56.7*			
A	**18.34**	7.95	1	0	2	14.53	**58.13**	10.09	0	0	1	27.76
B	38.08	**49.1**	8.6	0	17.44	57.23	55.89	**95.96**	12.46	0	15.2	70.44
C	9	44.81	**33.77**	1	18.6	109.62	9.5	66.8	**36.19**	1	17.3	95.97
R	0	5	8.18	**2.6**	2	70.31	0	0	2	**0.9**	2	12.19
T/In	6.3	14.62	10.5	0			6.14	15.92	9.89	0.8		
Entrants	25.26	128.48	164.71	13.49			28.13	83.77	171.6	9.36		
Law			*χ²=35.48*						*χ²=71.56*			
A	**8**	1	0	0	0	6	**13.07**	6	1.96	0	0	8.91
B	10.98	**30.02**	1	0	0	19.98	15	**36.86**	4.53	1	3	30.33
C	3.96	23.83	**12.81**	2.45	2	21.89	0	22.49	**11.7**	2	3.87	15.33
R	1	7	10.79	**4.5**	1.5	46.94	0	3.6	2	**0**	0.6	6.04
T/In	1	2	1	0			0	1	0	0		
Entrants	5	26.87	29.79	5.29			3	37.19	26.91	2.2		
Education			*χ²=108.52*						*χ²=74.35*			
A	**13.72**	2.6	0	0	1	6.88	**19.89**	3	1	0	0	24.7
B	8.5	**20.6**	2	0	4.52	29.7	20.64	**59.95**	16.9	0.7	4.92	64.62
C	3.4	47.25	**24.3**	0	12.83	70.45	1.87	36.88	**83.87**	2	13.25	97.22
R	1	26.15	100.4	**33.11**	14.22	263.9	0	0	23.79	**4**	4	42.02
T/In	5.4	6.3	14.9	11.91			2	10.8	10.68	1		
Entrants	16.57	64.83	93.49	28.79			7.13	27.57	108.98	13.87		

Notes: 'T/In' refers to transfers into the discipline from another discipline. 'T/Out' refers to transfers from the discipline to another discipline within the NZ university system. 'Exits' refers to researchers who exited the NZ university system, and 'Entrants' refers to researchers entering from outside the NZ university system.

6. Decomposition of entry, exit and quality transformation to AQS growth

Further insight into the nature of the differences among universities and discipline groups in their dynamics can be obtained by decomposing the *AQS* changes into component contributions arising from exits, entrants and quality transformations. The decomposition method suitable for this purpose is one that recognises that to improve the research quality of an institution, there are several ways in which it can transform the quality of its stock of researchers. These include retaining good researchers, creating opportunities to improve the research skills of those researchers who remain within the institution, 'managing out' the lower-quality researchers, and recruiting new researchers of a higher quality than incumbent or exiting researchers.

Institutions do not have complete control over all these changes. Competition for research skills, contractual and legal obligations, and individuals' career choices and retirement decisions impinge on the extent to which these transitions can be managed by an institution. Hence, many of the observed flows may be the result of other forces, but at the margin the institution can be expected to have an influence through human resource management policies such as recruitment decisions, performance management, training and the moulding and support of a strong research environment.

The required decomposition can be obtained by suitably modifying the relevant transition matrix, as follows. Let the initial and final *AQS* for the specified group be denoted by *Q*1 and *Q*2. The aim is thus to decompose *Q*2-*Q*1 into components. The *AQS* can be calculated for the final period, using an assumption that there are no entrants into any category: this is denoted by *Q*3. Furthermore, it is possible to obtain the *AQS* in the final period, by setting all exits and entrants to zero: this is denoted *Q*4. The assumption of no exits is applied by supposing that those recorded as exiting remain in the quality category in which they were placed in the initial period: that is, the diagonals of the flow matrix are augmented by the number of (FTE) exits. The difference, *Q*4-*Q*1, therefore reflects the effect of quality transformations (QTs) made by those who remain in the system. The difference, *Q*3-*Q*4, reflects the separate effect of exits. Finally, the difference, *Q*2-*Q*3, measures the effect of entrants. The sum of these differences adds to the total change, *Q*2-*Q*1.

The components, for each university (all disciplines) and discipline group (all universities) are shown in Table 6.[20] This reveals several persistent patterns. The net impact of exits on the *AQS*s

[20] In producing the results in Table 6, the transfers into each university from another NZ university (T/In) were treated as entrants, and transfers out of a university by someone moving to another NZ university (T/Out) were treated as exits.

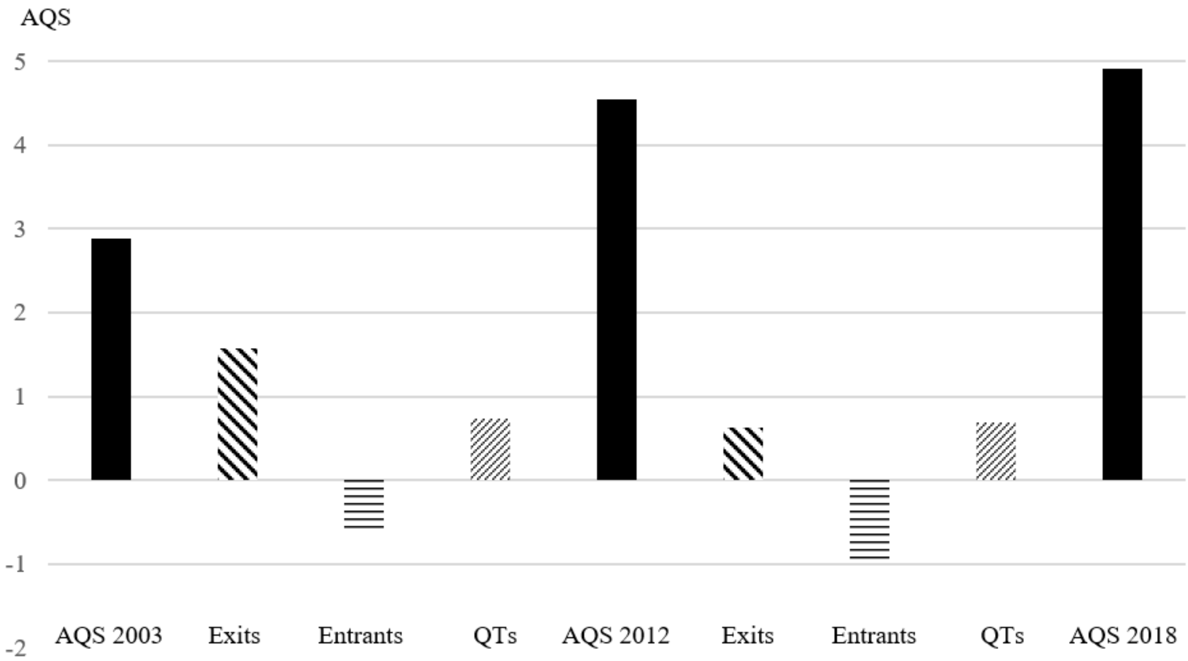
is positive for all universities and disciplines in both periods; the net impact of entrants is always negative; and the net impact of quality transformations is always positive. These contributions, for all universities combined, are summarised by Figure 2, which reveals three characteristics. First, the positive contribution from exits was much larger in 2003 to 2012 than the subsequent period: it fell from 1.57 to 0.63. Second, the negative contribution from entrants was larger in the second period: it increased from -0.63 to -0.96. Third, the contribution from the quality transformation of researchers was similar in both periods (at 0.73 and 0.69 in the respective periods).

Table 6. Contributions of exits, entrants and quality transformations to changes in university and discipline AQSs

University/ Discipline	*AQS* 2003	Exits (*Q*3-*Q*4)	Entrants (*Q*2-*Q*3)	QTs (*Q*4-*Q*1)	*AQS* 2012	Exits (*Q*3-*Q*4)	Entrants (*Q*2-*Q*3)	QTs (*Q*4-*Q*1)	*AQS* 2018
All	**2.88**	1.57	-0.63	0.73	**4.55**	0.63	-0.96	0.69	**4.91**
AUT	**0.77**	2.00	-0.16	0.54	**3.15**	0.57	-0.86	0.87	**3.73**
Lincoln	**2.56**	1.15	-0.67	0.47	**3.51**	1.29	-0.92	0.66	**4.54**
Massey	**2.10**	1.76	-0.30	0.55	**4.11**	0.54	-0.65	0.56	**4.56**
Auckland	**3.67**	1.40	-0.91	0.73	**4.89**	0.75	-1.01	0.75	**5.38**
Canterbury	**3.55**	1.02	-0.62	0.65	**4.61**	0.69	-0.75	0.50	**5.05**
Otago	**3.18**	1.60	-0.57	0.64	**4.85**	0.52	-1.10	0.59	**4.86**
Waikato	**2.98**	0.87	-0.07	0.43	**4.21**	0.69	-0.53	0.58	**4.95**
VUW	**3.11**	1.75	-0.42	0.93	**5.38**	0.32	-1.00	0.64	**5.34**
Medicine	**2.93**	2.06	-1.24	0.74	**4.49**	0.70	-1.26	0.62	**4.55**
Engineering	**3.00**	1.83	-0.77	0.51	**4.57**	0.70	-1.10	0.84	**5.01**
Core science	**3.79**	1.91	-0.78	0.39	**5.31**	0.64	-1.18	0.51	**5.28**
Management	**2.21**	1.35	-0.34	0.72	**3.95**	0.50	-0.55	0.61	**4.51**
Acc Fin Eco	**2.41**	1.24	-0.08	0.39	**3.96**	0.40	-0.69	0.42	**4.09**
Humanities	**3.17**	1.24	-0.43	0.76	**4.74**	0.65	-0.78	0.81	**5.43**
Agriculture	**3.65**	1.75	-1.20	0.75	**4.95**	0.92	-1.35	0.93	**5.45**
Law	**3.04**	1.46	-0.55	1.12	**5.07**	0.38	-0.61	0.66	**5.50**
Education	**1.38**	1.61	-0.15	0.89	**3.74**	0.46	-0.62	0.44	**4.01**

Turning first to exits, their impact on the *AQS* for the university system during 2003 to 2012 is, on average, more than twice the impact of each of the other two sources of change in the *AQS*. As shown in Table 3, the largest number of exits in this period were of R researchers: over 70 per cent of the stock of Rs in 2003 exited the university system by 2012. Because of the large exit of Rs, there were fewer Rs in the stock of researchers by 2012 (only about 14 per cent of the 2003 number) and there were fewer entrants of Rs during 2012 to 2018. Therefore, the net impact of exits during 2012 to 2018, while still positive, is substantially smaller than in the earlier period, at 13.8 per cent of the initial 2012 *AQS*.

Figure 2. Contributions to changes in all-universities AQS of exits, entrants & quality transformations



During the second period, the largest number of exits were of Cs and there were more B and A exits than during 2003 to 2012. This is unsurprising because, as the quality of the stock of researchers improves, the quality of exiting researchers will tend to rise, for a given turnover rate. The exit pattern is consistent with the response to incentives described in section 3.1. In addition, there is a large range in the impact of exits during 2003 to 2012. At the top end of the range are AUT, Massey and VUW which had the highest percentage improvements in *AQS*s during the first period. The average and range of contributions of the impact of exits on university *AQS*s are smaller in 2012 to 2018. Only Lincoln had a rise in the contribution of exits, and this university had the highest percentage growth in *AQS* in the second period. Lincoln had a relatively high exit rate of Rs in the second period, following a relatively low exit rate in the first period.

The effect of entrants on *AQS* is consistently negative, implying that the average research quality of entrants was lower than the *AQS* of the initial stock of researchers. This is the case in both periods. The size of this effect among universities and disciplines varies inversely with the initial *AQS*.[21] The absolute size of the negative impact of entrants is larger in the second period, but the percentage impact on the *AQS* for all universities is about 21 per cent in both periods. Even though the suggested responses discussed in section 3.2 are supported, this pattern reflects the situation where, as the *AQS* rises, the scope to hire researchers with QCs above or even close to the institution's average research quality gets increasingly more difficult. This is one reason why rates of improvement of university and discipline group research performance increase at a diminishing rate, as is evident from Figure 1; see also Checchi *et al.* (2020) and Buckle *et al.* (2020).

The net impact of quality transformations is, not surprisingly, consistently positive. This reflects decisions to attract and retain good researchers who are likely to improve over time. Nevertheless, this is the average effect of those who improve and those who decline in quality, while remaining within the institution. This pattern is similar in both periods, consistent with incentive effects discussed in section 3.3.

There are differences between universities and disciplines in the range of the effects of exits, entrants and quality transformations. For universities, the largest range in both periods is in the contribution of exits to improved *AQS*s. For disciplines, the largest range in both periods is in the contributions of entrants to improved discipline *AQS*s. The range of contributions from quality transformations are smaller than for exits and entrants in both periods and the ranges, though slightly higher for disciplines, are smaller both for universities and disciplines.

7. Decomposition of *AQS* changes into quality and discipline composition changes

One further way for a university to improve its *AQS*, not so far discussed in detail, is to exploit the systematic differences among discipline groups by changing the discipline composition of its researchers.[22] Changes in the overall discipline shares between 2003 and 2018, reported in Table 1, are not large. Nevertheless, these do in some cases appear to be related to the initial *AQS.* For example, Education had the lowest initial *AQS* and the largest reduction in the share

[21] The correlation coefficients for universities are -0.6 in the first period and -0.35 in the second period. The same relationship is evident for disciplines; the correlation coefficient is -0.7 in the first period and -0.55 in the second.
[22] Changes in the discipline composition of staff, following the introduction of performance measures by many states in the USA focussing on the evaluation of teaching, are reported by Payne and Roberts (2010).

of researchers.[23] The next lowest initial *AQS* was for Management, which also experienced a reduction in the overall share of researchers. Agriculture and Engineering had relatively high initial *AQS*s and saw increased shares over the period. By contrast, Medicine had the largest share increase but a relatively low initial *AQS*, and Core Science, with a reduction in its share, had a relatively high initial average quality.

The present section is thus concerned with the question of the extent to which, for individual universities, their *AQS* changes can be attributed to the changing discipline composition of its staff compared with the changing quality of its researchers. It is possible to decompose the change in the *AQS* into two terms. One term reflects the change in *AQS* attributed to the changing quality of its staff, given the final discipline composition. The second term reflects the change in *AQS* attributed to the changing discipline composition of the university, given the initial quality of staff. However, a different decomposition is possible, having a first component reflecting the change in *AQS* attributed to the changing quality of its staff, given the initial discipline composition, and a second term reflecting the change in *AQS* attributed to the changing discipline composition of the university, given the final quality of staff. As there is no special presumption in favour of either of these decompositions, one approach is to take the arithmetic mean of the components.[24]

The decompositions are shown in Table 7. During 2003 to 2012, all the increase in the *AQS*, for all universities combined, came from quality changes. There is some variation among universities: the contributions from discipline composition changes are in every case small and the proportional contributions range from zero for Lincoln to 7 per cent for Waikato. A similar feature is evident during 2012 to 2018. In the second period the percentage contribution arising from quality improvement is again the dominant influence for all universities combined: the overall *AQS* would have been 3 per cent higher in the absence of any change in the overall discipline composition. In the cases of Otago and VUW, the small reduction in quality is either more than offset (in the case of Otago) or partially offset (in the case of VUW) by a change in discipline contribution.[25]

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[23] Education numbers were clearly affected, in the early years of the PBRF, by substantial legislated institutional changes involving the merger of colleges of education with universities.

[24] In the earlier analysis of the contributions of exits, entrants and transformations to the change in *AQSs*, the perspective unambiguously concerns movement from an earlier to a later period, so only one expression of the decomposition is relevant. The present context involves changes arising from differences in the composition of the population.

[25] VUW illustrates the type of quality and composition effects that underlie a change in a university *AQS*. VUW continued to reduce its share of researchers in relatively low *AQS* disciplines, such as Education (by 3.3 per cent) and Management (by 2.2 per cent) and increased its share of researchers in the higher quality disciplines such as

Table 7. Quality and composition change contributions to improvements to each university's research quality

University	Increase in *AQS* 2003 to 2012	Attributed to: Quality	Composition	Increase in *AQS* 2012 to 2018	Attributed to: Quality	Composition
All	**1.67**	1.67	0.00	**0.36**	0.37	-0.01
AUT	**2.38**	2.36	0.02	**0.58**	0.60	-0.02
Lincoln	**0.95**	0.95	0.00	**1.03**	1.03	0.00
Massey	**2.01**	1.95	0.06	**0.45**	0.44	0.01
Auckland	**1.22**	1.17	0.05	**0.49**	0.49	0.00
Canterbury	**1.06**	1.03	0.03	**0.44**	0.38	0.06
Otago	**1.67**	1.65	0.02	**0.01**	-0.03	0.04
Waikato	**1.23**	1.14	0.09	**0.61**	0.58	0.03
VUW	**2.27**	2.22	0.05	**-0.04**	-0.10	0.06

Notes: This table shows the absolute changes to a university *AQS* attributed to changes in research quality and discipline composition. The proportions attributed to these two components can be calculated by dividing the amount attributed by the increase in *AQS*.

It appears that NZ universities generally (the main exception being for education) did not exploit strategies involving reductions in the size of academic departments. This contrasts with the experience of some other countries; see, for example, Hare (2003) and Adams and Gurney (2010). There are of course teaching commitments, and other strong constraints which would prevent senior managers from imposing substantial variations in staff/student ratios.

8. Assessing sustainability of researcher dynamics

There is no doubt (as seen from Table 2) that New Zealand universities in 2003 had a large proportion of R researchers, and that it was inconsistent with the incentive structure created by the PBRFS. Indeed, the subsequent high exit rate and low recruitment rate of Rs over 2003 to 2012 illustrates this point. The large reduction in the number and proportion of R researchers implies that, if prior to 2003, universities were satisfied with the quality distribution of researchers, the post-PBRFS environment changed what they considered to be a desirable

Core Science (by 4.8 per cent), Engineering (by 3.4 per cent) and Medicine (1.3 per cent). However, although Core Science is a discipline with a relatively high *AQS*, it is lower than the FTE weighted average *AQS* for all other researchers at VUW and therefore contributed to the slight reduction in its overall *AQS*. It also reduced its share of researchers in Humanities (by 1.6 per cent) which has a relatively high *AQS*, and this also contributed to the slight fall in VUW's *AQS* in 2018.

distribution. Moreover, once the stock of R researchers had fallen to only 5 per cent by 2012, further adjustments to the quality distribution of researchers required a different response in the subsequent 2012 to 2018 period.

It has been seen that the period 2012 to 2018 did indeed experience a different pattern of transition dynamics, one that resulted in a sustained low level of Rs coupled with a growing share of A and B researchers; see Table 3. This was achieved by a higher retention of As and Bs and a higher positive quality transformation rate. The differences in the transition dynamics between the first and second periods suggests a sequencing of priorities in the way universities managed to improve the average research quality of researchers. This involved a process of entry and exit that resulted in the initially relatively high proportion of lower-quality researchers being replaced by higher-quality researchers, and greater emphasis on retaining higher quality researchers.

The present section presents a further approach, involving the use of the observed dynamics to generate an equilibrium stock of researchers. In equilibrium, the exits and entries, combined with transitions among quality categories, are such that the distribution of researchers across QCs remains constant.[26] This equilibrium distribution can be compared with the actual stocks observed at the end of each assessment period. A large disparity and an unrealistic equilibrium distribution suggest that the changes observed since the PBRFS was introduced cannot be sustained indefinitely. Hence, it is reasonable to argue that the changes are sufficiently large to have been induced by the new incentives. No extraneous factors exist that could otherwise explain the nature of the transitions.

Using the transition matrix and vector of births in Table 2, the equilibrium stocks of researchers for each of the periods 2003 to 2012 and 2012 to 2018, for all universities combined, are shown in Table 8. The equilibrium total stocks for the 2003 to 2012 transitions exceed actual stocks in 2012 by about 23 per cent. It is therefore reasonable to suggest the transition dynamics generating the evolution of the quality of researchers at New Zealand universities after 2003 represents to some extent a structural shift in response to the introduction of the PBRFS, and this path cannot be expected to continue indefinitely. While equilibrium stocks exceed actual stocks for each QC in 2012, the largest differences are in the stocks of R, followed by A researchers.

[26] The equilibrium can be expressed in terms of the (convergent) sum of powers of the square transition matrix, and compares with the sum of an infinite geometric progression; see Buckle and Creedy (2019a).

The equilibrium total stocks for the 2012 to 2018 transitions exceed actual stocks in 2018 by about 26 per cent. This large difference between the implied equilibrium and actual stocks in 2018 also suggests that a structural shift in the transition dynamics generating the improvement in the quality of researchers since 2003, continued during 2012 to 2018. Although the nature of the dynamics changed during the second period, they continued to generate large differences between the actual and simulated equilibrium stocks. This is also illustrated by the differences between the actual *AQS*s in 2012 and 2018 and the implied equilibrium *AQS*s. The value of the implied equilibrium *AQS*s are 4.46 for the 2003 to 2012 dynamics and 3.90 for the 2012 to 2018 dynamics. The actual values shown in Table 6 are 4.55 for 2012 and 4.91 in 2018. Both values are in excess of the equilibrium values, by about 2 per cent in 2012 and 26 per cent in 2018.

Table 8. Initial and equilibrium portfolios and QC distributions: all universities combined

QC	2003	2012	Equilibrium 2003-12	% Diff	2018	Equilibrium 2012-18	% Diff
A	424	832	1339	60.9	1159	1248	7.7
B	1689	2475	2511	1.5	2894	2522	-12.9
C	2212	2639	2928	11.0	2819	3566	26.5
R	2206	304	923	303.6	183	1567	756.3
Totals	6531	6250	7701	23.2	7055	8903	26.2

Notes: Actual portfolios for each QC and the transition frequencies and entrants applied to expression (8) to derive equilibrium distributions of portfolios by QC are derived from Table 2. %Diff is the percentage difference between the equilibrium stocks and actual stocks where %Diff = 100*{[(Equilibrium stock-Actual stock in t+1)/Actual stock in t+1]-1].

The question arises of whether the unsustainable transition dynamics for the total university system observed for the two periods were generated by the behaviour of some or all universities, and some or all discipline groups. Using the same method applied to all universities combined, the transition matrices and vector of entrants for each university and each discipline group (derived from the data shown in Tables 4 and 5) were applied to expression (9) to generate the equilibrium distribution of researchers by QC, for each of the periods 2003 to 2012 and 2012 to 2018. The results for individual universities are shown in Table 9, and for discipline groups in Table 10.

Table 9 reveals considerable variation between the universities in the extent to which the equilibrium stock of researchers generated from the 2003 to 2012 transitions exceeded total actual stocks in 2012. The differences between the implied equilibrium stocks and actual stocks in 2012 range from 76.5 per cent (AUT) to 7.3 per cent (Massey). Clearly, the transition rates during the years following the introduction of the PBRFS and up to 2012 were not sustainable in the long term. As expected, the largest proportional difference between equilibrium and actual stocks arises in the R category. However, several universities had large differences between equilibrium and actual stocks of A researchers.

Table 9. Initial and equilibrium QC distributions for each university

	AUT	Lincoln	Massey	Auckland	Canterbury	Otago	Waikato	VUW
Long-run equilibrium stocks in each QC, 2003 to 2012 transitions								
A	188	24	137	303	102	296	106	228
B	252	59	334	620	235	575	177	352
C	321	110	456	734	272	581	183	260
R	102	34	110	242	126	144	79	107
Totals	863	227	1037	1899	735	1596	545	947
Actual 2012 stocks								
A	19	18	96	288	81	180	39	112
B	132	52	342	636	270	504	201	340
C	279	104	482	632	267	485	201	190
R	59	26	46	73	25	26	33	15
Totals	489	200	966	1629	642	1195	474	657
% ED	6.5	13.5	7.3	16.6	14.5	33.6	15.0	44.1
Long-run equilibrium number in each QC, 2012 to 2018 transitions								
A	109	29	190	348	79	242	42	217
B	307	50	361	655	178	486	140	449
C	535	79	526	794	251	744	171	502
R	294	27	233	307	83	380	65	259
Totals	1245	185	1310	2104	591	1852	418	1427
Actual 2018 stocks								
A	47	22	131	391	106	229	60	173
B	252	75	420	734	256	556	203	400
C	390	80	464	620	235	573	165	292
R	52	5	27	30	9	34	6	18
Totals	741	182	1042	1775	606	1392	434	883
% ED	68.0	1.6	25.7	18.5	-2.5	33.0	-3.7	61.6

Notes: The actual stocks for each discipline in each period are derived from the transition matrices in Table 4. The equilibrium values are derived using entrants during 2003 to 2012 (top panel) and during 2012 to 2018 (3rd panel) and the transition rates are derived from actual transition rates in each period. The vector of births for each of the individual universities and disciplines are the sum of the 'Entrants' and 'Transfers. For the entire university system these net out and hence the vector of entrants for the university system is 'Entrants' only (as shown in Table 2).

A substantial variation between the implied equilibrium and actual stocks of researchers persisted in the second period from 2012 to 2018. The large differences for AUT, Otago and VUW persisted, the difference increased for Massey and Auckland. However, some universities (Lincoln, Canterbury and Waikato) had equilibrium stocks close to actual stocks in 2018. The distributions of R stocks continued to be a substantial source of the difference, and larger difference between the equilibrium and actual stocks emerged in the distribution of C researchers.

Table 10. Initial and equilibrium QC distributions for each discipline

	Medicine	Engineering	Core Science	Management	Acc Fin Eco	Humanities	Agri-culture	Law	Edu-cation
	Long-run equilibrium stocks in each QC, 2003 to 2012 transitions								
A	470	237	132	63	39	219	149	22	82
B	662	432	212	136	117	517	268	66	128
C	858	455	185	191	134	560	281	70	175
R	230	84	22	60	52	161	56	24	96
Totals	2220	1208	551	450	342	1457	754	182	481
	Actual 2012 stocks								
A	232	106	99	26	33	161	97	30	48
B	587	360	196	149	104	571	250	91	168
C	719	382	170	192	150	509	227	55	235
R	82	23	6	22	31	36	17	12	74
Totals	1620	871	471	389	318	1277	591	188	525
%ED	37.0	38.7	17.0	15.7	7.5	14.1	27.6	-3.2	-8.4
	Long-run equilibrium stocks in each QC, 2012 to 2018 transitions								
A	322	217	108	74	62	349	148	45	29
B	668	436	218	179	123	602	240	84	96
C	1120	557	251	201	205	632	308	79	217
R	470	295	107	79	88	268	49	40	94
Totals	2580	1505	684	533	478	1851	745	248	436
	Actual 2018 stocks								
A	304	175	110	37	26	266	158	31	52
B	675	456	225	199	139	681	273	107	138
C	914	410	194	164	170	442	232	47	245
R	66	19	8	20	15	16	12	6	22
Totals	1959	1060	537	420	350	1405	675	191	457
%ED	31.7	42.0	27.4	26.9	36.6	31.7	10.4	29.8	-4.6

Notes: The actual stocks for each discipline in each period are derived from the transition matrices in Table 5. The equilibrium values are derived using actual entries during the 2003 to 2012 period (top panel) and during the 2012 to 2018 period (3rd panel) and the transition rates are derived from actual transition rates in each period. %ED = 100*{[(Equilibrium stock -Actual stock)/Actual stock]-1].

Table 10 compares the levels and quality distribution of equilibrium and actual researcher stocks for the two periods for discipline groups. Although it reveals a smaller range of differences than occurred for universities, nevertheless a large variation exists. The largest difference between equilibrium and actual stocks in 2012 were for Medicine, Engineering and Agriculture. An important source of the differences for all disciplines is again the distribution of Rs, and As for some disciplines (Medicine, Engineering and Agriculture especially). For 2012 to 2018, there are more disciplines with large differences between equilibrium and actual stocks. The distribution of Rs remains a key source of this difference, along with the distribution of Cs, especially for Medicine, Engineering, Agriculture and Humanities.

The equilibrium stocks of researchers provide a stark indication of the large extent of the changes in the distribution of the quality of researchers since the introduction of the PBRFS. This is despite the many characteristics of universities which make structural change difficult. This provides indirect support for the idea that the observed changes in the quality distribution of researchers since the introduction of the PBRFS do represent, to some extent, the influence of the introduction of the new research funding system.

9. Conclusions

This paper has examined the transformation of NZ universities, in terms of the quality of their research, during the period 2003 to 2018, following the introduction of a PBRFS. This substantially changed the incentives facing individual researchers and university managers. Information about the metrics used, such as Quality Categories for individuals and the Average Quality Score for universities and disciplines, are obviously not available for pre-PBRFS years. However, by considering the ways in which the incentives are likely to influence entries, exits and quality transformations, it is argued that the consistency of the large changes in NZ universities with these incentives provides support for the argument that those changes were directly influenced by the PBRFS, and were not generated by other external factors or other existing university characteristics.

It was found that the dynamics of universities and disciplines depend in particular ways on the initial structure of universities and discipline groups. The analyses reported here demonstrated substantial heterogeneity among universities and discipline groups, and differences in the pattern of transitions over time, that are consistent with the responses expected from the special nature of incentives created by the metric used. In addition, the extent of heterogeneity was found to be lower during the later PBRFS period, 2012 to 2018.

The paper has also decomposed *AQS* changes into those arising separately from the patterns of entries, exits and transformations of individuals over time. Furthermore, *AQS* changes were decomposed into contributions arising from changes in the discipline composition within a university, and changes in research quality of the university's disciplines groups. Generally, New Zealand universities were found not to have used a strategy of substantially changing their discipline composition (that is, of substituting higher-quality discipline groups for lower-quality, as measured by the *AQS*). However, during the first period 2003 to 2012, all universities substantially reduced the number of researchers in the Education discipline group.

The sustainability of changes was examined by considering, for each university, the structure that would arise from holding the transition proportions and the entries constant over time, until an equilibrium structure is reached, where entries just compensate exits from each Quality Category. The result that the equilibrium stocks of researchers does not appear to be sustainable lends further support for the argument that the changes made over the PBRFS period were directly influenced by the incentives, operating in the context of an initial position.

It is also noteworthy that one way of improving average research quality of NZ universities, namely the increased concentration of research in high-quality universities, has not followed the introduction of the PBRFS. Similarly, a way to improve average quality within each university is to reduce the size of low-performing discipline groups relative to the high-performing groups. This method has also not been followed systematically.

The substantial slowing down in the rate of quality improvement, during the period 2012 to 2018, compared with the earlier period 2003 to 2012, suggests that it is perhaps worth reviewing the form of the PBRFS, in view of the high compliance and administrative costs. Furthermore, the major contribution to the average quality improvement in all universities and disciplines has resulted from the large number of exits of lower-quality researchers. This also suggests that the extensive process, and information required, that is used to distinguish among somewhat arbitrary higher-quality categories is no longer necessary.

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