Comparability of NSC mathematics scores and former SC mathematics scores: How consistent is the signal across time?

Karin Hunt*, Miracle Ntuli‡, Neil Rankin‡, Volker Schöer‡ and Claire Sebastiao‡

* School of Computational and Applied Mathematics, University of the Witwatersrand
‡ African Microeconomic Research Umbrella (AMERU), School of Economics and Business Sciences, University of the Witwatersrand, email: Volker.Schoer@wits.ac.za

Abstract

Schools provide learners with a set of skills which they take with them after they leave school. The pupil's competence and preparedness is supposed to be reflected in the school leaving scores which are then used as signals by employers and further education institutions to pick the most appropriate applicant. Universities in particular need a consistent signal of academic potential to admit students who have a comparable academic ability to current students. However, the introduction of the National Senior Certificate (NSC) in South Africa has led to the admission of students who seem inadequately prepared for tertiary institutions, especially with regards to their mathematical preparedness. Using a standardised 1st year test which was written in 2006 and repeated in 2009 and 2010 at the University of the Witwatersrand, we compare the signalling ability of the NSC school leaving mathematics scores with the former Higher Grade (HG) mathematics scores with respect to the students' mathematical preparedness. Our findings suggest that the NSC mathematics scores are inflated by around 20-25 percentage points compared to the former HG mathematics scores. However, once deflated, the NSC scores are very good predictors of mathematical preparedness. These results are consistent across the two NSC cohorts which should allow admission offices to set more appropriate minimum requirements for university admission.

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Introduction

The introduction of Outcomes-Based Education (OBE) in 1998 and the change from the former Senior Certificate (SC) to the new National Senior Certificate (NSC) in 2008 in South Africa were aimed at addressing the inequalities and inadequacies of the education system inherited from the apartheid system. The aim of these curriculum changes is to produce school leaving matriculants who can become thinking, competent future citizens (Engelbrecht and Harding, 2008) with creative and problem solving abilities - skills which South African learners were consistently lacking (Botha, 2002). Also, in recognition of the need to be numerically literate and mathematically competent in today's world, the new curriculum makes at least one mathematical subject mandatory for the school leaving examination. The success of this policy change has been increased numbers of pupils taking mathematics or mathematical literacy in their final examinations. However, with any change in the education system comes the question of whether the new system prepares pupils sufficiently and adequately for their lives after school. Potential employers and further education institutions use scores from school leaving examinations as signals of the pupil's competence and preparedness. However, the changes in the South African education system have created uncertainty about the quality and signalling ability of the South African school leaving examination (Paton, 2009). While more pupils have obtained university exemption and have performed better in mathematics since the inception of the NSC in 2008, universities have observed increasing failure rates in first year courses of student cohorts that are admitted on NSC examination scores (Govender, 2010). In response, various South African universities have raised their admission requirements for the 2011 intake in order to curb the failure rates and ensure that only students with the appropriate level of academic preparedness are admitted (Bowman, 2010). A key question facing universities is by how much should the admission requirements be raised in order to admit a sample of NSC students that exhibit a similar level of academic potential as students that were previously admitted on SC Higher Grade (HG) scores?

In order to address this question we use a standardised test for a compulsory mathematics course (Computational Mathematics APPM1004) for commerce students at the University of the Witwatersrand to investigate the comparability of the NSC mathematics scores to the former HG mathematics scores. The structure and content of the test was very similar in 2006 (SC students) and in 2009 and 2010 (NSC students). By investigating performance in this test we are able to compare the NSC mathematics scores with the former HG mathematics scores using a common instrument. Furthermore, by comparing two years of NSC mathematics we are able to compare the consistency of the NSC mathematics scores as signals of academic ability.

NSC: Academic potential signal and admission requirements

Universities observe the academic performance of their current student cohorts and match that performance to the current students' school-leaving examination scores. This correlation is then used to set the entrance requirements for the next cohort of applicants. As long as the assessment and the marking system of the performance of school leaving pupils is consistent over time, this approach allows universities to use school-leaving scores as an indicator of new applicants' academic potential (Burton and Ramist, 2001). Because school-leaving exams in South Africa are nationally standardised and quality controlled, the signalling ability of such scores is reasonably comparable across applicants with different characteristics and over time. However, when there is a break in the signal, universities set entrance requirements with uncertainty. When the entrance requirements are set too high, students who have the potential to perform well in the programme might be excluded and educational resources are under-allocated. On the other hand, when the entrance requirements are set too low, educational resources might be over-allocated. Universities would have to raise additional resources and/or reallocate resources to support struggling students. More importantly, the incorrectly admitted students would struggle considerably with the requirements of their chosen programme and most likely would fail, lose the money they paid for fees and waste one whole year which could have been used to look for work or to study at a different, more appropriate institution/programme. Both outcomes are inefficient, but it is the second case which has the highest cost for students who can least afford it. It is for this reason that universities have a moral obligation to set entrance requirements that ensure that students have a fair chance of passing the course for which they have been admitted (Bowman, 2010). In both cases, additional admission procedures to identify applicants who do not meet the formal minimum entrance requirements but still have the academic ability to perform well could be used (Herman, 1995; Latif Al-Nasir and Sachs Robertson, 2001; Nel and Kistner, 2009).

School mathematics scores are particularly important signals of the applicant's potential for university degrees that are quantitative in nature. Mathematics scores have been shown to be reliable predictors of academic potential in various quantitative courses (Konvalina, Wileman and Stephens, 1983; Adair, 1991; Lunt, 1996; Smith and Naylor,

2001; van Walbeek, 2004; Parker, 2006; Sadler and Tai, 2007; Smith & Edwards, 2007). This explains why, in the admission to such courses, South African universities expect a relatively high level of competency in mathematics as an entrance requirement.
A structural break in the signal of school leaving scores happened in 2008 with the replacement of the former SC by the new NSC. Not only does the NSC introduce a different curriculum founded on OBE, but also a different set of assessment criteria and marking system. To reduce the uncertainty around the NSC and to enable universities to still use their admission criteria, the Department of Education (DoE) released a conversion key (Table 1) between the former HG symbols and the new NSC scores.

Table 1: Higher Grade SC to NSC conversion

Percentage	80–100	70–79	60–69	50–59	40–49	30–39	20–29	10–19	0–9
HG	A	B	C	D	E	F	G	H	I
NSC	7	6	5	4	3	2	1	1	1

Source: Wits Admissions Office, 2008

According to the conversion key, applicants who obtained Level 4 in NSC mathematics should exhibit the same level of preparedness as a former SC applicant who obtained a HG "D" symbol. This conversion key informed the admission requirements set by the universities for the 2009 and 2010 intake of NSC students. Various South African universities, including the University of the Witwatersrand, which previously required applicants to achieve 40% (symbol E) for HG mathematics as a minimum entrance requirement for some quantitative courses, expected some level of grade inflation with the introduction of the NSC and raised the minimum requirements for the first intake of NSC matriculants to 50% (level 4) for NSC mathematics.

The outcome was a significantly larger number of enrolled students in 2009 who, if the conversion key was correct, had on average performed better in mathematics relative to previous SC cohorts. Unfortunately, the conversion seems faulty even with the raised entrance requirements. Table 2 shows a comparison of enrolment and pass rates of various quantitative disciplines at the University of the Witwatersrand between 2006 and 2010.

Table 2: enrolment numbers and pass rates for a selection of quantitative courses at the University of the Witwatersrand (2006-2010)

	2006		**2007**		**2008**		**2009**		**2010**	
	Enrolled Students	**Pass rate (%)**	**Enrolled Students**	**Pass rate (%)**	**Enrolled Students**	**Pass rate (%)**	**Enrolled Students**	**Pass rate (%)**	**Enrolled Students**	**Pass rate (%)**
MATH1001[1]	376	77	399	51	419	47	636	31	611	22
MATH1014[2]	501	69	616	63	666	71	1126	38	1030	60
MATH1010[3]	268	79	323	81	369	75	432	63	456	59
PHYS1010[4]		46		41		36		50		49
CHEM1012[5]	364	41	419	54	515	38	639	28	768	36
ECON1000[6]	1480	67	1353	46	1437	52	2100	36	1675	45
APPM1004[7]	959	66	901	63	892	64	1235	46	792	63
Average		63		57		55		42		48

It is evident that the introduction of the NSC and admission requirements based on the conversion key increased enrolment numbers, but significantly lowered pass rates. This confirms the previously voiced uncertainty about the quality of the new curriculum (Rogan, 2007; Cross, Ratshi, and Rouhani, 2002) and the appropriateness of the NSC as a signal of ability (Parliamentary Monitoring Group, 2009; Ramphele, 2009, Jansen, 2009, Paton, 2009).

[1] MATH1001 is the first year mathematics course for students who major in mathematics, chemistry or physics.
[2] MATH1014 is the first year mathematics course for students who major in engineering.
[3] MATH1010 is the first year mathematics course for students who major in biological or earth sciences.
[4] PHY1010 is the first year introductory course to physics at the faculty of science.
[5] CHEM1012 is the first year introductory course to chemistry at the faculty of science.
[6] ECON1000 is the first year introductory course to economics at the faculty of Commerce, Law and Management.
[7] APPM1004 is the first year mathematics course for students who major in commerce related courses at the faculty of Commerce, Law and Management.

However, despite this evidence that the conversion key is misleading, very little is known about the correct conversion between the former SC scores and the new NSC scores. To the authors' knowledge, only two published papers have analysed the conversion between the former SC and new NSC. The first (Nel and Kirsten, 2009) uses the Stellenbosch University access test as a benchmark and shows that NSC mathematics scores are inflated by 20 percentage points at the lower performance groups, but converge at the top. The paper argues that "the scores of especially the lower group of performers could possibly be too high and that quite a number of students have an unrealistic perception of their own academic ability – particularly as far as their skills in specific subjects such as Mathematics are concerned" (Nel and Kirsten, 2009: 971). These findings are supported by Schöer *et al* (2010) who show a similar inflation of NSC mathematics scores at the lower levels of the range of university admission as well as convergence at the top. This paper claims that the same range of academic abilities which previously had been spread between HG mathematics scores of 40-100%, i.e., 60 percentage points, have now been compressed into a relatively narrow percentage range of 30 percentage points between NSC mathematics scores of 70-100%. The authors conclude that the NSC does not allow universities to sufficiently distinguish between different levels of academic abilities. Importantly, since inflation is greatest at the bottom of the range of scores used for admission, getting the conversion wrong for these students is most detrimental since it is likely that many of these students will be on the margin between passing and failing at university.

Both of these papers compared the first cohort of NSC applicants (2009) with the last cohort of SC applicants (2008). However, the results might have been driven by the characteristics and composition of these two cohorts. The inflated scores of the 2009 cohort might be the outcome of the quality of the NSC mathematics examination paper. According to Umalusi (2009), the cognitive demand of the 2008 NSC mathematics examination paper was closer to the former Standard Grade (SG) paper than the HG paper. The 2009 NSC mathematics examination paper, on the other hand, reflected a higher standard and required a cognitive demand closer to the former HG mathematics paper (Parliamentary Monitoring Group, 2010). Thus, the results might be very different for a comparison of the second NSC cohort. Furthermore, the last cohort of the SC to matriculate in 2007 had been partially exposed to the new OBE curriculum. In order to address both these issues, we use the performance data of a first year commerce course at the University of the Witwatersrand in 2006 and compare this to the performance of the 2009 and 2010 cohorts. The 2006 student cohort (students who matriculated in 2005) would have been more firmly embedded within the old, skills based, SC matriculation syllabus during their school career as opposed to students matriculating post 2005 (Engelbrecht and Harding, 2008). Comparing the 2006 cohort to both NSC cohorts allows us to control for cohort specific characteristics and composition and to investigate whether the signalling ability of the NSC has changed between 2008 and 2009 (i.e. students in their first year of university in 2009 and 2010 respectively).

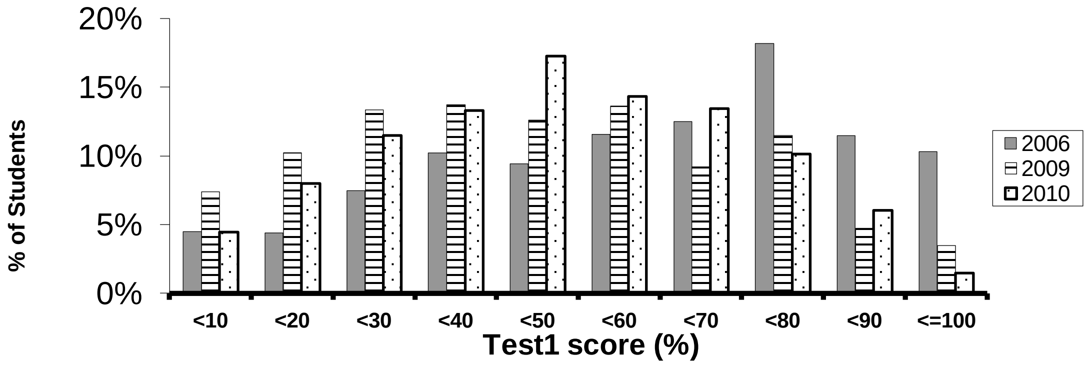
Computational Mathematics tests comparisons at Wits

In order to make comparisons between the cohorts we need an instrument that is independent from the school-leaving mathematics marks but highly correlated with them. Furthermore, this instrument needs to be unchanging between the cohorts. In order to do this, we exploit the fact that all commerce students at Wits have to register for Computational Maths I (APPM1004). APPM1004 is a terminating service course in mathematical skills for students registered for Bachelor of Commerce and Bachelor of Accounting Science degrees, hence the emphasis of the course is less towards the development of mathematicians and more towards the practical use of mathematical tools in business and economic applications.

Due to the uncertainty of the signalling ability of the NSC mathematics scores, the teaching staff of the APPM1004 course made the deliberate decision in 2009 to rewrite the same first test (Test 1) that was written in 2006. To investigate the consistency of the NSC mathematics scores over time, the APPM1004 teaching staff again decided in 2010 to repeat the same test. Test papers have always been collected after the test and are not made available to students in the following year. This allowed the APPM1004 teaching staff to repeat very similar tests over the three years.

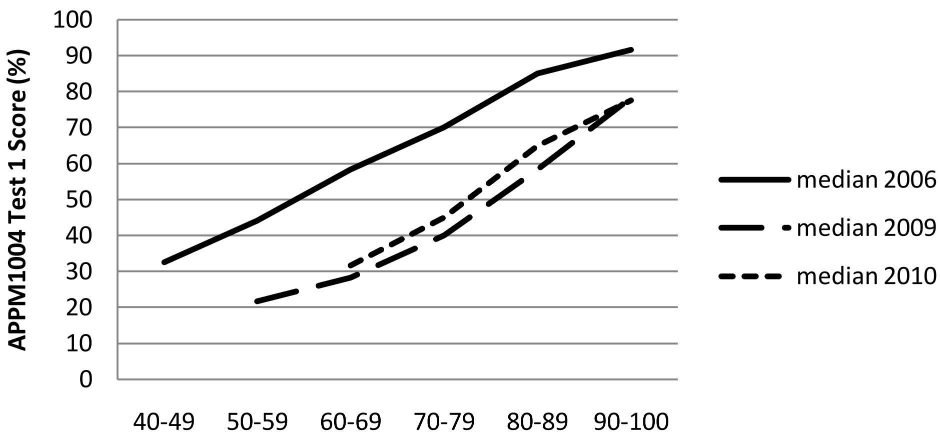
Figure 1 reports the results of the APPM1004 Test1 for the years 2006, 2009 and 2010. While the score distributions of both NSC cohorts are relatively similar, the score distribution of the SC cohort of 2006 is considerably skewed to the left. This indicates that the SC cohort performed better than both NSC cohorts while the 2010 cohort performed similar to the 2009 cohort, despite the supposed increase in the cognitive demand of the 2009 NSC Mathematics examination paper. This is also reflected in the pass rates for Test1. 63% of the 2006 cohort passed the first test, while only 43% and 45% passed the same test in 2009 and 2010 respectively.

Figure 1:APPM1004 Test1 comparison: score distribution (2006, 2009, 2010)



However, the aggregate picture can be misleading. These results include older students, repeating students as well as foreign students. We delimit the data of each cohort and exclude any student who did not matriculate in South Africa the year prior to being registered for APPM1004 for the first time. After delimiting the data, we have 787 students for 2006, 1048 in 2009, and 654 in 2010. Furthermore, we transform the SC mathematics scores of 120 students who were admitted with SG mathematics scores in 2006 into HG equivalents by deflating the SG mathematics scores by 20 percentage points[8]. We use this data to compare the correlation between the school leaving mathematics scores and the median students' performance in the APPM1004 Test 1 shown in figure 2.

Figure 2: Test 1 performance by Mathematics score category (median score)



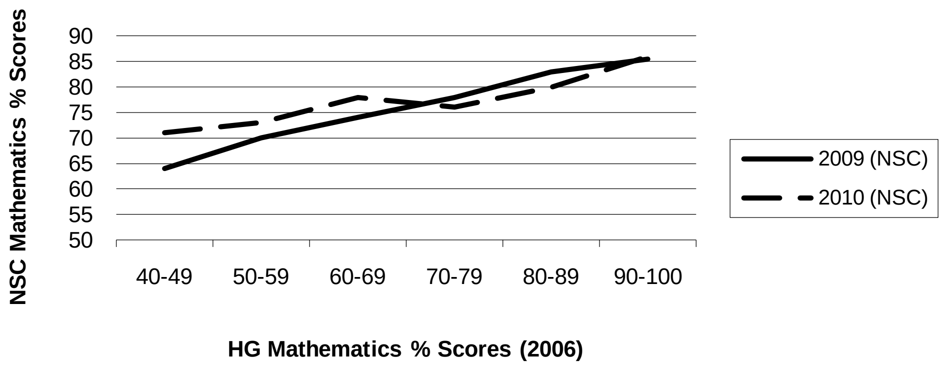
The results in figure 2 suggest that for each mathematics score range, the median student with HG mathematics performs consistently around 20 percentage points better than the median student with NSC mathematics, irrespective of the year in which the NSC student wrote the NSC school leaving mathematics examination. Only at the top end do we see a decrease in the difference of the median students' performances.

In order to control for possible cohort effects that might affect the results in figure 2, we use propensity score matching. This allows us to investigate the comparability of the NSC mathematics scores over time and to create a more accurate conversion key between the NSC mathematics scores and the former HG mathematics scores. The advantage of propensity score matching is that we first match individuals from one cohort with individuals from the other cohort that are "similar" in their observed individual characteristics including their gender, age, race and other information that the students provided on their university admission forms[9]. Thus, we construct two samples of the 2009 and 2010 cohorts that are as similar as possible to the 2006 cohort with respect to their observed characteristics

[8] This is in line with the universities admission office practice which converts SG marks into HG equivalents by subtracting 20 percentage points. Most courses at Wits which imposed a 40% HG minimum admission requirement accepted students who achieved a minimum of 60% in SG.
[9] Enrolment data was obtained from the Wits admissions office.

and their performances in the APPM1004 Test 1 which effectively creates statistical twins across the SC and the NSC cohorts. We then compare the NSC mathematics scores of the 2009 and 2010 first-year students with the HG mathematics scores of their 2006 statistical twins with similar observable characteristics and similar performances in the APPM1004 Test 1. Surprisingly, the results as shown in figure 3 are consistent across both NSC cohorts despite the differences in the quality of the examination papers.

Figure 3: HG vs NSC Mathematics conversion



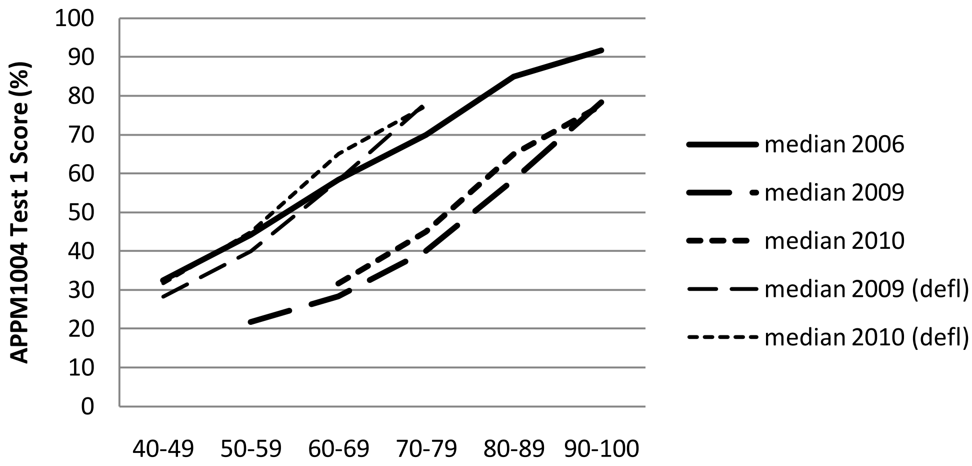
Using the results of the propensity score match, we construct a conversion key between the HG mathematics scores and the NSC mathematics scores as is reported in Table 3.

Table 3: Conversion key based on propensity score match (2006 HG to 2009 and 2010 NSC)

Percentage category	80–100%	70–79%	60–69%	50–59%	40–49%
Higher Grade	A	B	C	D	E
NSC (DoE key)	7	6	5	4	3
NSC (propensity score match)	7	7	6	6	5

The results of the propensity score match suggests that the NSC mathematics scores are inflated by around 20-25% at the lower HG performance levels, i.e., students in 2009 and 2010 who obtained 60-69% for NSC mathematics exhibit the same level of academic performance as students in 2006 who obtained 40-49% for HG mathematics. This confirms earlier findings by Nel & Kistner (2009) and Schöer *et al* (2010). In order to check the accuracy of this new conversion key we deflate the NSC mathematics marks by 20 percentage points and analyse the median performance of the students in APPM1004 Test1 in 2009 and 2010 compared to the median performance of students in 2006 by mathematics score category.

Figure 4: Test 1 performance by Mathematics score category (median score after deflation)



Once deflated, the median performance at each mathematics score category is similar across all three cohorts (figure 4). This suggests that raising the university admission requirements for school leaving NSC mathematics to level 5 (60-69%) would generate a sample of admitted students with a similar academic performance spread as a sample of former students who had been admitted with 40% and above in HG mathematics. This also confirms that NSC students who had been admitted with less than level 5 (60-69%) into university programmes which previously required a minimum achievement of HG symbol "E" (40-49%) did not possess the mathematical preparedness required for the mathematical rigour of such programmes.

However, once the NSC mathematics scores are deflated by 20 percentage points and NSC matriculants with a mathematics score of 60-69% are equated to former HG matriculants with a mathematics score of 40-49%, the NSC mathematics score categories seem to be a better discriminator of ability. The range of Test1 scores (between the 10^{th} and the 90^{th} percentile) at each mathematics score category is lower for the NSC cohorts than for the SC cohort (figures 5-7). For instance, if we compare the range of test scores of the 40-49% HG mathematics category of the 2006 cohort with the range of test scores of the 60-69% NSC mathematics category of both NSC cohorts (thus taking inflation into account) we see that, while the median test score for all three cohorts is around 31%, the test scores of the 2006 cohort range from 3% to 57% whereas the test scores of the 2009 and 2010 NSC cohorts range from only 8% to 55% and 12% to 53% respectively. This is reflected across most mathematics score categories in the shorter length of the lines of the NSC cohorts in figures 6 and 7.

Figure 5: Test 1 score variance by mathematics score category (2006 SC cohort)

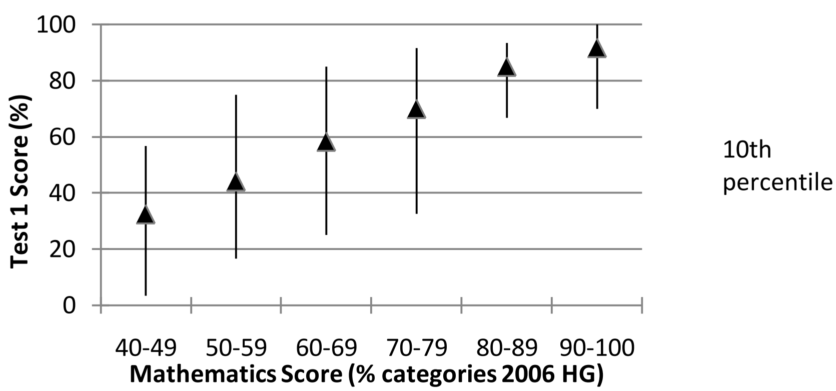


Figure 6: Test 1 score variance by mathematics score category (2009 NSC cohort)

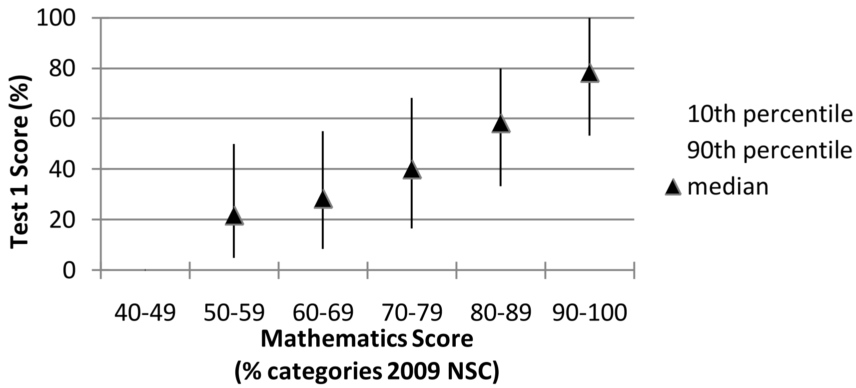
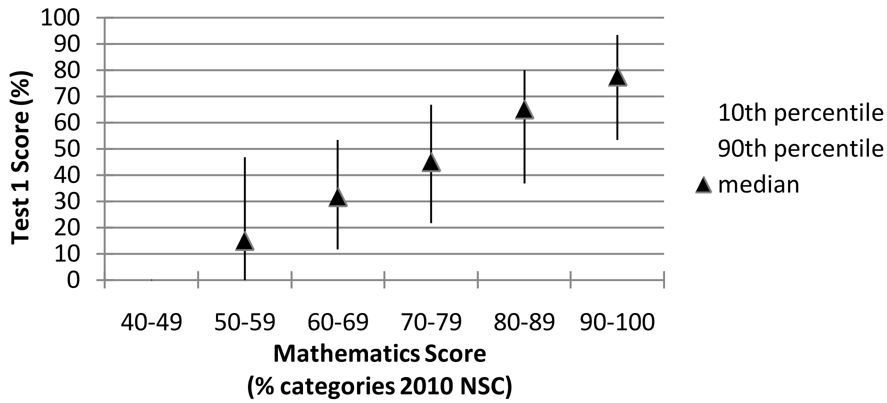


Figure 7: Test 1 score variance by mathematics score category (2010 NSC cohort)



This suggests that, except for the top end HG categories, the NSC categories are better at distinguishing university level performance within categories. The robustness of these results is confirmed by the results of a quantile regression controlling for the students' individual characteristics (see appendix tables 4a and 5a). The quantile regression shows that the performance spread of the students in the various mathematics score categories is more bunched around the median for the NSC matriculants compared to the SC matriculants. Positive coefficients show that the NSC student's test score is higher than the SC matriculant's test score while a negative coefficient indicates that the test score of the SC matriculant is higher than the test score of the NSC student. At the lower performance levels (10^{th} and 25^{th} percentiles) NSC students perform better than their SC counterparts (as shown by the positive coefficients) while at the higher performance levels (75^{th} and 95^{th} percentiles) NSC students consistently get lower marks than their SC counterparts (negative coefficients). Only at the higher mathematics score ranges (80% and above) do the SC matriculants perform consistently better at all performance levels (percentiles) than the NSC matriculants.

Conclusion

University admission should be guided by the idea that students who have been admitted into a particular degree have a fair chance of passing. This implies that the minimum admission requirements represent a threshold that is high enough to exclude students who do not have the necessary academic preparedness to cope with the workload of the programme. If universities considered their previous HG mathematics scores to be sufficient minimum thresholds, then they need an appropriate conversion key between the NSC scores and the HG scores. In order to admit a cohort of NSC matriculants into university which exhibits a similar performance spread to the former SC matriculants, universities should increase the required NSC mathematics score by 20 percentage points above the former required HG mathematics score. This result is consistent for a comparison of NSC mathematics scores with two different cohorts of students with HG mathematics scores (the 2006 cohort of this study and the 2008 cohort of the previous published studies). If universities considered the previous performance spread of the SC cohorts as underperforming, then they should raise it by even more, i.e. above 20 percentage points.

However, once deflated and correctly aligned with the former HG mathematics scores, the NSC mathematics scores seem to be a better signal of academic ability. Specifically, they are better at differentiating between the different academic abilities around the mathematical score categories which are generally used for university admission (around 50% and above), and in these categories are better at excluding students at the bottom of the distribution (i.e. those that fare worse in Test 1). Furthermore, the signal of the NSC mathematics scores is consistent for both 2009 and 2010 when benchmarked against the former HG mathematics score. This should give admission offices some confidence in the use of the NSC mathematics scores in future admission rounds.

Appendix

Table 4a: Quantile regression results, percentage points differences in Test 1 between HG and NSC mathematics categories by percentile (2006 SC cohort vs 2010 NSC cohort)

HG (%)	**40-49**	**50-59**	**60-69**	**60-69**	**70-79**	**80-89**	**80-89**	**90-100**	**80-100**
NSC (%)	**60-69**	**70-79**	**80-89**	**70-79**	**80-89**	**90-100**	**80-89**	**90-100**	**80-100**
10th percentile	**5**	**10*** **	**13.3*** **	**0**	**5**	**-15**	**-21.7*** **	**-11.7**	**-20*** **
25th percentile	**1.6**	**6.7*** **	**8.3***	**-5** **	**-5$**	**-10** **	**-25*** **	**-18.3*** **	**-23.3*** **
50th percentile	**-1.6**	**3.3**	**3.3**	**-13.3*** **	**-6.7** **	**-5$**	**-20*** **	**-8.3** **	**-16.7*** **
75th percentile	**-1.6**	**-3.3$**	**0**	**-15*** **	**-10*** **	**-5***	**-15*** **	**-8.3*** **	**-15*** **
90th percentile	**-5**	**-8.3*** **	**-3.3$**	**-18.3*** **	**-11.7**	**-1.7**	**-15*** **	**0**	**-8.3*** **

Statistical significance: *** p<0.01, ** p<0.05, * p<0.1, $ p<0.2

Table 5a: Quantile regression results, percentage points differences in Test 1 between HG and NSC mathematics categories by percentile (2006 SC cohort vs 2009 NSC cohort)

(%)	**40-49**	HG **50-59**	**60-69**	**60-69**	**70-79**	**80-89**	**80-89**	**90-100**	**80-100**
NSC (%)	**60-69**	**70-79**	**80-89**	**70-79**	**80-89**	**90-100**	**80-89**	**90-100**	**80-100**
10th percentile	**7.7**	**5.8** **	**19.2*** **	**-5.8$**	**9.6** **	**-9.6**	**-25*** **	**-9.6**	**-23*** **
25th percentile	**5.8$**	**3.9$**	**10.6*** **	**-9.6*** **	**-1.0**	**-11.5*** **	**-26.9*** **	**-15.4** **	**-23*** **
50th percentile	**1.9**	**0**	**1.9**	**-17.3*** **	**-3.9**	**-4.8$**	**-19.2*** **	**-9.6*** **	**-17.3*** **
75th percentile	**1.9**	**-5.8$**	**0**	**-19.2*** **	**-8.6*** **	**-5.8*** **	**-17.3*** **	**-9.6*** **	**-17.3*** **
90th percentile	**-3.8**	**-9.6*** **	**-3.85***	**-17.3*** **	**-9.6*** **	**0**	**-13.5*** **		**-7.7*** **

Statistical significance: *** p<0.01, ** p<0.05, * p<0.1, $ p<0.2

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