A blurred signal? The usefulness of National Senior Certificate (NSC) Mathematics marks as predictors of academic performance at university level[1]

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Internationally, performance in school Mathematics has been found to be a reliable predictor of performance in commerce courses at university level. Based on the predictive power of school-leaving marks, universities use results from school-leaving Mathematics examinations to rank student applicants according to their predicted abilities. However, in 2008 the structure and scope of school-leaving examinations changed in South Africa from the former Senior Certificate (SC) to the new National Senior Certificate (NSC). This structural break seems to create fluctuations in the signalling ability of the school-leaving marks. South African universities are unsure about how well the current NSC Mathematics marks reflect the underlying numerical competence of students, given that a high number of the 2009 student intake failed their first-year core courses across faculties. This paper estimates a deflator for the new NSC Mathematics marks relative to the former Higher Grade (HG) Mathematics marks, by comparing performance in similar first tests of two commerce subjects, Economics 1 and Computational Mathematics, between the 2008 and 2009 first-year cohorts. The results indicate that the signalling ability of the NSC Mathematics marks is reduced significantly. Instead of differentiating students according to their abilities, the new NSC Mathematics marks compress students with a wide range of abilities and disabilities into a very narrow range of percentage marks.

Keywords: university admission, first-year commerce courses, matric Mathematics, National Senior Certificate, academic ability, ability signalling

Introduction

In 2009 the number of first-year students accepted to study at the University of the Witwatersrand (Wits) was significantly higher than in previous years. The majority of the students applying to Wits for entry in 2009 were also the first matriculants to obtain the new school-leaving National Senior Certificate (NSC) instead of the former Senior Certificate (SC). Along with the expansion of the student body, there has been an observable decrease in the average test marks from 2008 to 2009 for first-year commerce courses at Wits. Considering that the NSC Mathematics marks of the 2009 student intake were on average 6% higher than the previous year's, we argue that the signalling ability of the NSC Mathematics marks had dwindled. Thus, due to the fluctuations in Mathematics marks as a reliable ability signal, admission standards were set too low, which led to the inappropriate admission of students to commerce degrees. The aim of this

paper is to create a deflator of the NSC Mathematics marks by comparing the school-leaving Mathematics marks of the first-year commerce students in 2008 with the school-leaving Mathematics marks of the first-year commerce students in 2009. The comparison will then be used to establish a more accurate conversion key between the Higher Grade matric Mathematics marks of the former SC and the new NSC Mathematics marks.

School marks as signals of academic ability at university level

In the admission process, South African (SA) universities rely heavily on marks obtained from standardised school-leaving examinations, namely, the former SC examinations (prior to 2008) and the new NSC examinations (awarded from 2008 onwards). Universities treat these certificate marks as indicators not only of the applicants' current knowledge, but also of their ability to progress successfully in their studies in the future. This is possible only if school-leaving examination marks are a consistently reliable signal of this knowledge and ability. Due to the fact that school-leaving examinations are quality controlled and standardised nationally, the marks are seen as reliable signals of ability for universities countrywide when comparing students against one another across time. This allows universities, based on observed correlations between previous students' marks in school subjects and their academic performance at university, to rank new applicants according to their academic ability at university level. If these marks are no longer reliable signals for ability, universities will have to find other ways to determine ability and potential – possibly by administering their own entrance tests.

School Mathematics marks are considered to be good predictors of academic performance for commerce-related subjects like economics, accounting and actuarial sciences (Parker, 2006; Smith & Edwards, 2007; Van Walbeek, 2004; Varua & Mallik, 2008). Therefore, when comparing the admission requirements for most commerce faculties in South Africa (SA), they require a relatively high Mathematics mark and put significant emphasis on the Mathematics mark as a requirement for admission. Across all universities, commerce degrees require at least a pass for Mathematics (NSC level 4) or more, and do not admit students who have studied mathematical literacy.

Understandably, SA universities cannot limit admission to only those students who have done well in the school-leaving examination, as this would neglect the universities' responsibility to promote access and equity in favour of their responsibility to maintain quality (Herman, 1995:271). The practice of using school marks as a signal of ability and the primary criterion for university admission is therefore not without its critics. In particular, critics argue that such a limitation would discriminate against students who may have the potential to do well at university, but have not been given the opportunity to achieve at high-school level. This is usually because of social conditions such as poverty, coupled with poor teaching and lack of basic resources, which result in low school-leaving certificate marks (Herman, 1995:268). Cross and Carpentier (2009) argue that SA universities are in the process of democratisation, and that the majority of students are increasingly "non-traditional students" from disadvantaged households, that "are more and more distant from the cultural and intellectual norms required by educational institutions, usually dominated by the elite" (Cross & Carpentier, 2009:7). In that respect, admitting only top-performing learners into tertiary institutions simply perpetuates existing levels of inequality in SA and creates a "form of educational apartheid" (Cross & Carpentier, 2009:7). One way of addressing this problem is through the implementation of gateway or bridging courses, which allow students from disadvantaged backgrounds to access universities while receiving adequate support for the first two years of study (Essack & Quayle, 2007). Examples of such gateway courses are the four-year academic development programme in the Faculty of Commerce at the University of Cape Town and the five-year study programme (5YSP) in the School of Engineering at the University of Pretoria. These programmes are generally one year longer than mainstream programmes to allow students to develop the necessary study skills. "The purpose of the 5YSP [at the University of Pretoria] is to create opportunities for students who have the potential to become engineers, but who do not meet the entrance requirements for a four-year study programme and/or are academically at risk because of their educational background" (Steyn & Maree, 2003:47). Placement in gateway courses is always based on the applicants' school-leaving marks combined with the results of

admissions tests (Du Preez, Steyn & Owen, 2008). Thus, the school marks are once again used to evaluate admission and placement into such development programmes. This requires school marks to be reliable signals of the students' academic ability or disability.

Another criticism is that high-school marks are measures of cognitive ability, whereas there are other non-cognitive abilities that are equally important for doing well at university, including persistence, motivation to succeed and self-discipline (Fraser & Killen, 2005; Heckman & Rubinstein, 2001). However, while these qualities have some predictive powers, high-school marks are still better signals of ability and future performance at university (Latif Al-Nasir & Sachs Robertson, 2001:284). This is mainly because school marks do not reflect only what students know, but also what non-cognitive abilities they have (Mohammad & Almahmeed, 1988:214). Research focused on investigating which variables are the best predictors of academic performance at university also usually finds academic performance at school to be the best predictor (Anderson, Benjamin & Fuss, 1994; Betts & Morell, 1999; Touron, 1987).

Therefore, for universities which rely so heavily on school-leaving examination marks as signals of ability, any structural break or significant fluctuation in the signal creates uncertainty, which could lead to inefficient decision making with respect to student admissions.

This structural break occurred in SA in 2008. The 2008 matriculants were no longer awarded the former SC on passing their examinations — instead they were awarded the new NSC. These students were taught using the outcomes-based education (OBE) system instead of the old skills- or content-based learning system that was organised into Higher and Standard Grade courses (Le Grange, 2007). From the outset, the OBE system was inundated with criticism and many were convinced that students would learn less than before (Cross, Ratshi, & Rouhani, 2002:180-183; Rogan, 2007:98).

In addition to the curriculum changes of the new system, there was also a change in the approach to the assessment and marking system. Students are no longer assigned symbols based on a numerical mark for examinations, but are instead assigned coded numbers that aim to indicate the level of proficiency obtained. Based on information provided by the Department of Education (DoE), higher education institutions like Wits developed a conversion key that allowed the admissions office to match the relationship between the former SC Higher Grade symbols and the new NSC levels.

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
Higher Grade	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 this key (replicated in Table 1) students who passed Mathematics on Higher Grade and obtained a "D" would now obtain a "4" under the NSC. Both of these marks were expected to reflect the same ability, which would result in students with more or less the same abilities as those in the previous year being admitted. When university registration numbers across South Africa increased noticeably, the DoE hailed it as evidence of the new curriculum's success[2]. While this might be true, the increase may also indicate that the comparative ranking of the old and the new marking systems was incorrect. Already in early 2009, parliament raised questions about the accuracy of the NSC matric marks and the potential inflation of marks, especially regarding subjects like Mathematics (Parliamentary Monitoring Group, 2009).

Many in the university community considered the standard of the 2008 NSC Mathematics paper to be too low, and proposed that it did not allow for an appropriate differentiation of ability among the

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2   Naledi Pandor, then Minister of Education, stated that, "we are convinced that the quality standard we have set for these examinations, the evidence of improvement and the continuing commitment to achieve quality for all learners will deliver the promise of the Freedom Charter that the doors of learning and culture are indeed open and accessible for all the learners in our system" (Pandor, 2009).

top students[3]. However, the DoE claims that, except for at the top end, the Mathematics paper was of an acceptable standard and comparable to the former SC Higher Grade level[4]. However, there is very little quantitative evidence that attempts to compare the NSC examination marks with the former SC examination marks.

Commerce tests comparisons at Wits

As part of the commerce curriculum at Wits, all commerce students have to register for Economics 1, Accounting and Computational Mathematics. While Accounting and Computational Mathematics are offered only to commerce students, Economics 1 is offered across faculties and draws students from the humanities, science, engineering and commerce.

In 2009, the number of commerce students at Wits increased unexpectedly by 25% from 2008. The first-year commerce students in 2009 scored on average 6% higher in their NSC Mathematics relative to the first-year commerce students in 2008. If the conversion key is correct, this should indicate that the 2009 cohort would perform much better than the 2008 cohort. However, in response to the overall scepticism about the true ability of the 2009 student intake, the computational Mathematics and the Economics 1 course lecturers deliberately set tests in the first block of 2009 that were very similar to the tests written in the first block of 2008 in order to compare these two cohorts. The tests are the introductory test (Test 0) for the first-year Computational Mathematics course and the first test (Test 1) of the first-year Economics course.
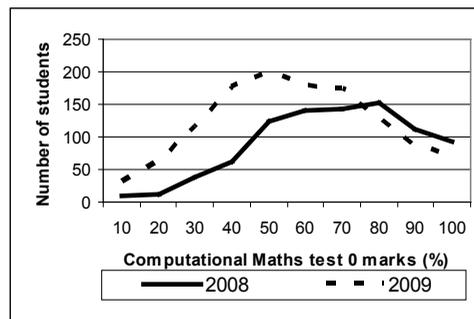

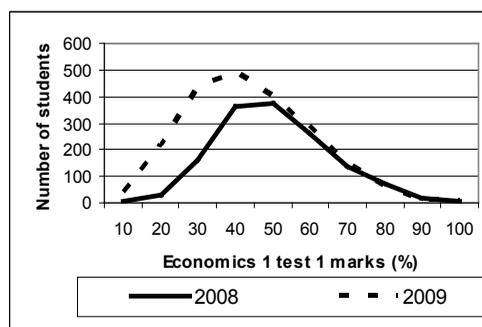**Figure 1:** Computational Mathematics test mark comparison

Figure 2: Economics 1 test mark comparison

3   Nan Yeld from the University of Cape Town (UCT) argues that the NSC Mathematics paper was too easy, and Penny Vinjevold, Deputy Director General of Education, states that "there wasn't enough differentiation at the top end, so that As and Bs were not a good predictor [of university success]" (Paton, 2009).

4   Vinjevold states that "if you got 50% for the [2008 NSC Mathematics] paper, then you were at [the former] Higher Grade level" (Paton, 2009).

The test results indicated the opposite situation. As can be seen from Figures 1 and 2, while the actual number of students in the upper mark categories is similar for both years, the number of students in the lower mark categories (<50%) diverges markedly. The increase in the number of failures in 2009 accounted for almost exactly the increase in the total number of students registered for both courses in 2009.

The test comparisons of the two commerce courses suggest that the NSC Mathematics marks of the 2009 cohort are not reliable signals of the students' academic ability and that the university has admitted students who do not have the necessary set of skills to pass commerce courses. However, a simple comparison of the two tests across different years might be misleading. Both test-mark distributions for the Computational Mathematics course and the Economics 1 course show the entire sample of students who are registered for the courses in 2008 and 2009, respectively. This includes repeat, foreign and older students, who matriculated long before 2007.

In order to compare the signalling ability of the Mathematics mark from the former SC to the new NSC Mathematics, we need to account for any other factor that might affect academic performance. Thus, we need to compare first-year students who entered the university in 2008 after completing matric in 2007 with first-year students who have similar individual characteristics as the 2008 students, but entered the university in 2009 after completing NSC in 2008. This will allow us to isolate the impact of the difference between the students' Mathematics abilities on their academic performance.

The individual student data for the 2008 and 2009 first-year student cohorts is drawn from the Wits student records. Students were removed from the sample if they: 1) had written their school-leaving examinations prior to 2007 or in a different country; 2) had repeated their school-leaving examinations in 2007 and 2008, i.e., had written the SC as well as the NSC examinations; 3) did not report their personal and/or school-specific information on their student files; and 4) did not write both the first economics test and the computational Mathematics test. This delimitation created a sample of 1445 first-year students of which 546 and 896 were enrolled in 2008 and 2009, respectively.

Methodology

For the analysis, we exploit the established relationship between a student's school Mathematics mark and their performance at university, in order to estimate the predicted Higher Grade Mathematics mark for students that wrote NSC Mathematics. To create the comparison between the two cohorts, we start by estimating a regression of the following form on the 2008 first-year students' sample:

$$y_i = \alpha + X_i'\beta + \chi english_i + \delta test_i + \varepsilon_i$$

Where:

y_i is the result that an individual obtained for the school-leaving Mathematics examination;

α is the constant term;

X_i is a vector of individual specific characteristics including gender, race, home province, whether the individual lives in university residence and whether the individual has financial aid;

*English* is the result that an individual obtained for school-leaving English examination;

test is the test mark that an individual achieved in either the Computational Mathematics Test 0 or the Economics 1 Test 1. In order to allow for a non-linear relationship we also introduce a squared-term.

ε_i is an error term.

The relationship between the Higher Grade Mathematics mark and the students' performance in the Computational Mathematics Test 0 and the Economics 1 Test 1 is estimated using Ordinary Least Squares (OLS). A number of different specifications are used in order to check the robustness of these results. The results from these regressions are then used to predict what the NSC students would have scored if they had written the 2007 Higher Grade Mathematics based on their individual characteristics and what they scored for Computational Mathematics Test 0 or Economics 1 Test 1.

Converting NSC Mathematics marks to HG Mathematics mark equivalents

In Figure 3 the kernel density function of the predictions based on the various regression specifications is presented. The actual Mathematics mark of the average NSC matriculant (dashed line) exceeds the actual Mathematics mark of the average Higher Grade matriculant (solid line), suggesting that the 2009 cohort should have a higher Mathematical ability than the previous year's intake. However, the predicted Higher Grade results for the NSC matriculants (dotted — using Computational Mathematics, dotted/dashed — using Economics 1) suggest that this is not the case. Instead, the faculty accepted a higher proportion of students with relatively low predicted Higher Grade Mathematics marks. In fact, many of those accepted would have scored less than 50% for Higher Grade Mathematics.
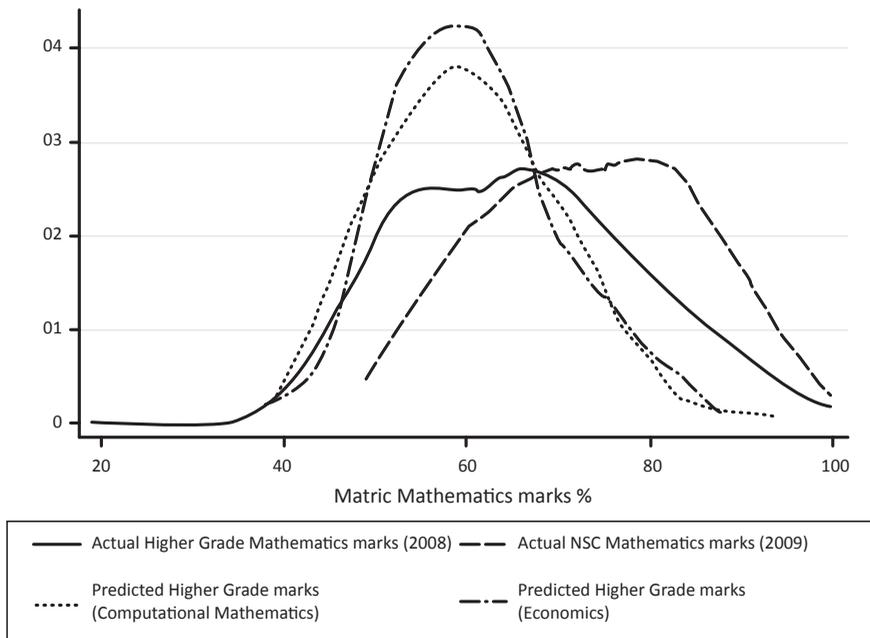
Figure 3: Actual and predicted Matric Mathematics mark distribution

The average actual NSC mark obtained for categories of predicted Higher Grade marks is reported in Table 2. Students of the 2009 cohort with a predicted Higher Grade Mathematics mark in the range of 40-49% (Higher Grade symbol "E") actually achieved an observed average NSC Mathematics mark in the range of 64-66%. This increased to 68-69% for those predicted to score a "D" (50-59%) in Higher Grade Mathematics. The Mathematics marks converge only towards the upper end of the spectrum.

Table 2: Actual NSC marks for predicted Higher Grade categories

Predicted HG Percentage		80-100	70-79	60-69	50-59	40-49	30-39
Matric HG symbol		A	B	C	D	E	F
Actual NSC percentage							
	Mean	92.4	85.7	77.4	69.1	63.6	56.4
Computational Mathematics	*Std dev*	*(3.88)*	*(7.37)*	*(9.77)*	*(9.42)*	*(8.03)*	*(4.96)*
	Mean	90.4	85.2	77.1	68.3	65.2	-
Economics 1	*Std dev*	*(5.16)*	*(8.38)*	*(10.17)*	*(9.99)*	*(8.99)*	-

To test the robustness of the above results and to eliminate the potential impact of the differences in the composition of the two cohorts, we use propensity score matching as an alternative approach. The advantage of propensity score matching is that we first match individuals from the 2008 cohort with individuals from the 2009 cohort that are "similar" in their observed individual characteristics. Thus, we construct a sample of the 2009 cohort that is as similar as possible to the 2008 cohort with respect to their observed characteristics. We then compare the Higher Grade Mathematics mark of the 2008 first-year student with the NSC Mathematics mark of the 2009 first-year student with similar observable characteristics and similar performances in the Computational Mathematics Test 0 and the Economics 1 Test 1. The propensity score matching process identified 260 matches for the Computational Mathematics test and 230 matches for the Economics 1 test.
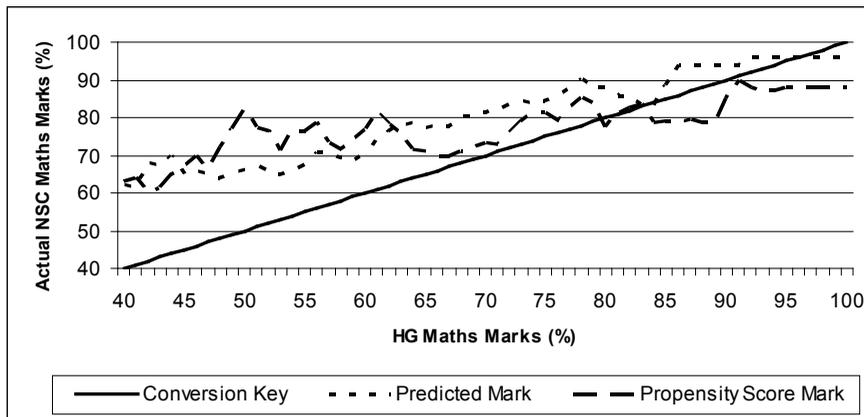
The NSC Mathematics mark of the matched 2009 first-year student is on average 12-13% higher than the Higher Grade partner's Mathematics mark. This difference is statistically significant. However, this is the average and across all matches, not along the distribution. The mean NSC Mathematics mark of 2009 first-year students compared to their matched Higher Grade partners grouped in the actual Higher Grade bands they scored is reported in Table 3. The results suggest that the former Higher Grade E (40-49%) is equivalent to, on average, between 70-72% in the new NSC Mathematics when comparing similar first-year students across the two years. This is significantly higher than the previously predicted 64-66%.

Table 3: Comparison of NSC Mathematics marks with Higher Grade matched partners (propensity score matching)

Percentage category		80-100	70-79	60-69	50-59	40-49	30-39
Matric HG symbol		A	B	C	D	E	F
NSC student							
	Mean	82.20	79.11	76.96	72.86	72.33	58
(Comp. Mathematics Test 0)	*Std dev*	*(11.68)*	*(11.58)*	*(10.92)*	*(11.43)*	*(11.91)*	-
HG matched partner							
	Mean	85.92	72.95	64.63	53.9	45.2	39
(Comp. Mathematics Test 0)	*Std dev*	*(5.27)*	*(2.58)*	*(2.89)*	*(2.66)*	*(3.19)*	-
	N	39	44	85	61	30	1
NSC student							
	Mean	81.15	75.59	76.05	76.19	70.4	67
(Economics 1 Test 1)	*Std dev*	*(9.06)*	*(11.34)*	*(13.09)*	*(10.62)*	*(11.39)*	-
HG matched partner							
	Mean	85.12	73.29	65.01	54.5	45.3	39
(Economics 1 Test 1)	*Std dev*	*(4.86)*	*(2.54)*	*(3.15)*	*(2.87)*	*(3.16)*	-
	N	32	44	70	63	20	1

Furthermore, the results suggest that the NSC mark does not discriminate sufficiently for the student's ability, but rather compresses students with substantial differences in ability indicated by their matched Higher Grade partners (40-100%) into a limited range of only 30% (70-100% in NSC marks). Thus, while an NSC matriculant who obtained a Mathematics mark of 70-80% could exhibit the same academic ability as a former SC matriculant who obtained 80% in Higher Grade Mathematics, another NSC matriculant who also achieved a Mathematics mark in the range between 70-80% could exhibit the same academic ability as a former SC matriculant who obtained only 40% in Higher Grade Mathematics. This compression is illustrated in Figure 4 by the distance between the solid line (direct conversion of NSC marks to Higher

Grade marks) and the lines for the predicted HG mark (short-dashed line) and the propensity score mark (long-dashed line) respectively. In the middle Higher Grade mark ranges (40-60%), the equivalent NSC Mathematics marks are inflated by around 24%. The inflation decreases as the marks converge at the top. However, it is also illustrated in Figure 4 that the NSC Mathematics marks did not allow top students to differentiate themselves from the rest.

Figure 4: NSC Mathematics marks compression

We can use the findings of the predictions and the propensity score matching to develop a more appropriate conversion key between the NSC Mathematics mark and the Higher Grade Mathematics mark based on the performance of the students in the two commerce courses. The relationship between the two Mathematics marks is outlined in Table 4.

Table 4: Former SC Higher Grade to new NSC conversion based on test marks of Economics 1 and Computational Mathematics

Percentage	80-100	70-79	60-69	50-59	40-49	30-39	20-29
Higher Grade	A	B	C	D	E	F	G
NSC (Applied key)	7	6	5	4	3	2	1
NSC (predicted)	7	7	6	5	5	4	4 and less
NSC (propensity score match)	7	6	6	6	6	5	

In 2008, Wits accepted students into the general BCom (Baccalaureus Commercium) with an E (40%) for Higher Grade Mathematics. In 2009, the admission requirement was a minimum of level 4 (50%) for NSC Mathematics. However, in Table 4 it is suggested that in order for the Wits to admit students who achieved at least an E (40-49%) for Higher Grade Mathematics, the level in 2009 should have been at least level 5 (65% according to the predicted NSC), if not closer to level 6 (71% according to the propensity mark matching).

Conclusion

Universities need reliable ability signals to select suitable student applicants for their degree programmes and to be able to place students who need support in designated support programmes. Until now, school marks have been considered sufficient for conveying the applicants' ability to handle the workload and requirements of tertiary education. Therefore, for universities to be able to identify and select suitable

applicants it is crucial that the new NSC school Mathematics marks function equally well as appropriate signals. However, the introduction of the NSC has left a structural break in this signal. This has created uncertainty in admissions offices, and a significant number of students have been admitted into programmes without being suitably equipped to handle the academic material.

Our results show that the NSC Mathematics marks of the 2008 matriculants do not signal the differences in numerical abilities (or disabilities) of the students sufficiently. Rather, the NSC Mathematics marks group students with substantially different abilities into a very narrow range of marks. Thus, NSC matriculants who achieved a mark of 70-100% have an academic ability similar to that of former SC matriculants who achieved 40% and more in Higher Grade Mathematics. This confirms that the signal of ability of the new NSC school-leaving Mathematics has weakened significantly.

The implications for students are even worse. They leave the school system with the expectation that their school-leaving marks signal their true ability. However, not only have universities accepted applicants who do not have the required Mathematical preparedness, but these universities could not use the school marks as reliable signals to place applicants into programmes more appropriate to their true ability level. Thus, for a large number of students, studying in 2009 has been a waste of financial resources and time. Furthermore, to adjust to the signalling problem, universities and education authorities could potentially overreact. While universities might raise their entrance requirements dramatically, education authorities might set much more difficult final examination. While both sides try to adjust to the new signal of the NSC, it is the school-leaving learner who will be affected negatively.

Acknowledgements

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