Mathematics & Science Education and Income: An Empirical Study in Japan

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Abstract: Since the second half of the 1990s, the decline in academic standards in mathematics and science among undergraduate students in Japan has been noted. Despite this, problems in science education have become increasingly severe, and their impact is having a mounting effect on Japan's economy. This paper studies the return to a university education in Japan by taking into account the relative ranking of the universities. We present an empirical analysis of how annual income differs depending on whether a major is natural science or humanities. We have found that science graduates have a higher average income than humanities graduates indicates that the added value they are producing is higher than that of humanities graduates. Of particular interest is the fact that a comparison of humanities graduates of A rank universities who did not sit admission examinations in mathematics with science graduates of B rank university showed that it was the science graduates who recorded higher average income at every age grade. The above comparison also reveals that even those humanities graduates of A rank universities who did sit admission examinations in mathematics are out-earned by science graduates of B rank universities in the under 30 and 55 and over age groups.

Keywords: Mathematics education, income, humanities, science, admission difficulty.

1. INTRODUCTION

Since the second half of the 1990s, the decline in academic standards in mathematics and science among undergraduate students in Japan has been noted (Okabe, Tose, and Nishimura 1999, Tsutsui, Nishimura, and Matsuda 2004). Despite this, problems in science education have become increasingly severe, and their impact is having a mounting effect on Japan's economy. There has also been a decline, in recent years, in the rate at which graduates are securing employment after graduation. This trend can be understood as a response by companies to the decline in quality of Japan's labor market, and therefore is not entirely unrelated to the challenges faced in science and mathematics education in Japan today.

Empirical studies casting light on the impact of mathematics learning on income include Urasaka *et al.* (2002) and Nishimura *et al.* (2006). These studies have demonstrated the positive influence that mathematics learning appears to have on the income of humanities (and social science) graduates of private universities in Japan. The findings of these analyses were based on data obtained by surveying graduates, mostly of economics, from three private universities. This paper represents an attempt to widen the scope of the investigation into the impact of science and mathematics learning on income by surveying science graduates as well as graduates of both private and public universities.

Kane and Rouse (1993) have looked at the relationship between credits acquired at university and annual income as a way of gauging the rate of return to a university education. Arcidiacono (2004) studies the college education process, estimated the difference in earnings among majors, and discusses the factors which determine earnings. Then, he shows that the observed premiums are generated by both the learning of math and science and the abilities of individuals choosing the different majors. O'Leary and Sloane (2005) examine income of university graduates in Great Britain according to their department of graduation. Wolniak *et al.* (2008) also show that the statistically significant differences exist in earnings among college majors by using alumni data. Especially, Math/Engineering majors earn higher income, which is consistent with our results in this paper.

This paper studies the return to a university education in Japan by taking into account the relative ranking of the universities[1]. We present an empirical

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[1]International comparative studies on the rate of return to education include Tostel, Walker, and Woolley (2002), Brunello and Comi (2004), and Tostel (2005). Studies focusing on the return of university education from a more general perspective include Wills (1986) and Card (1999).

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analysis of how annual income differs depending on whether a major is natural science or humanities.

This paper is structured as follows: Section 2 outlines the method used in the survey, while Section 3 discusses the impact on income of mathematics learning according to admission difficulty and whether graduates studied a science or humanities subject, as well as the significance of the resulting disparities.

2. SURVEY OUTLINE

The survey was conducted online. There has been considerable discussion on the various merits and demerits of online sampling. The merit of the online survey is that the recovery is higher than the mailing method. This is because the respondents accept most of the questions in the survey even the sensitive questions such as the education career, since they basically agree to cooperate to answer the questions when they are enrolled on the list of the online survey company. The demerit is the sample selection bias caused from internet availability. However it is less important today since the internet is widely used in Japan. In fact we have recently conducted the survey research by hybrid of mailing and personal in-home surveys methods too. The results are very similar to those of the online survey.

We need to secure as large a sample size of university graduates as possible was considered paramount in this case, hence the selection of the online survey method.

The online survey company used for this study, NTT Resonant Inc., is known for the good quality of its respondents; it has in place a number of processes to maintain this quality, such as verifying the address and surname of registered users, and limiting the number of responses to one per household.

A pre-survey was conducted between June 6 and June 12 2008, principally in order to filter university graduates out from all registered monitors. 89,102 samples of the pre-survey were sent out, with 30,603 valid responses returned; a response rate of 34.34%. Based on the information obtained through the pre-survey, the main survey was conducted between June 12 and June 16 2008. Of 6,870 samples, 2,152 valid responses were received; a response rate of 31.32%.

The variables used in the analysis will be discussed later; here, some of the overall trends of the 2,152 valid samples obtained from the main survey will be discussed.

The average age of respondents was 42.57 years, and around 70% were men. 67.1% of respondents had a partner, and the average number of children per respondent was 1.08. Average annual income was 5,289,000 yen (67,548 US dollars). Of the 2,152 samples, 1,611 respondents—around three quarters—were employees with income, and of these around 80% were full-time permanent employees. In terms of occupation, administrative roles and technological/ research & development roles were most common, while the most common levels of employment were general staff, unit heads, and senior staff members.

Table **1** shows the average annual income for male and female employees with income. The average age was almost the same for male science and humanities graduates, while for women, humanities graduates were on average one year older than science graduates. The average income for humanities graduates was 5,834,000 yen (men: 6,600,000 yen, women: 3,631,000 yen), while for science graduates it was 6,815,000 yen (men: 7,020,000 yen, women: 4,528,000 yen); science graduates are earning, on average, around 1,000,000 yen per year more than humanities graduates. It goes without saying that science graduates will have been required to study mathematics; this data on income disparity may be a very pointed indication of the effect of mathematics learning. What can be stated with confidence at this

Table 1: Comparative Annual Income of Humanities and Science Graduates (Currently Employed)

	All Employees			Men			Women		
	N	Average age	Average income (unit: 10k yen)	N	Average age	Average income (unit: 10k yen)	N	Average age	Average income (unit: 10k yen)
Humanities graduates	988	41.1	583.4	733	41.5	660.0	255	40.0	363.1
Science graduates	644	41.0	681.5	591	41.2	702.0	53	38.9	452.8

point is that the average annual income of science graduates is higher than that of humanities graduates.

3. IMPACT ON INCOME OF MATHEMATICS LEARNING

The survey data obtained was used to estimate the impact of mathematics learning on income. The variables used for estimates are shown in Table **2**, and the descriptive statistics are shown in Tables **3** and **5**. Income itself becomes an explained variable, so the estimates only apply to those respondents who are employees with income.

In the earlier studies, Urasaka *et al.* (2002) and Nishimura *et al.* (2006), we conducted the analysis by limiting respondents to humanities (specifically, social science) graduates in three leading private universities of very similar ranking in terms of academic standards. This meant that other factors (such as ability) regarding the respondents were controlled. However, in this survey, there is no such uniformity in the data. In order, then, to control these factors, the ranking (in terms of academic standards) of universities will be applied to the data.

University ranking was determined using the admission difficulty league table published for 2008 by Benesse Corporation. This league table compares the prerequisite academic standard for admission to departments and universities in terms of deviation values.

These deviation values are not just introduced as explanatory variables; rather, the sample data was divided into three ranks, C (deviation value of less than 50), B (50-59), and A (60+), and these were used to consider whether there were any differences in the impact of mathematics learning on income. For this reason, the results of our previous studies can most appropriately be compared with the estimates obtained for data on graduates from A rank universities in this analysis.

Another way in which this study differs from our previous studies is the inclusion of public university graduates in the sample data; such graduates represent a little more than 20% of the total. However, data from public school graduates did not appear to bring about any particular changes in the results below, so this data did not explicitly control other factors.

Next, analysis was performed to estimate impact on income for graduates of all disciplines—including science. The estimation model and admission difficulty rankings were almost identical with those for the humanities graduates, and the estimates obtained were used to create income profiles, which were then used in an attempt to compare the results for humanities and science graduates, and for differently ranked groups.

3.1. Humanities Graduates

First the data for humanities graduates is presented. According to the descriptive statistical data, shown in Table **3**, the average income for humanities graduates rose in accordance with admission difficulty level, as follows: graduates of C rank universities had an average annual income of 4,527,000 yen; graduates of B rank universities an average annual income that was approximately 1.19 times that of C rank university graduates (5,391,000 yen); and graduates of A rank universities an average annual income that was approximately 1.55 times that of C rank university graduates (7,039,000 yen). It should be noted that the average age of respondents was around 40 years, with the largest difference in age being between 4 and 5 years.

Also of note is that the proportion of respondents who took at least one mathematics examination (mathematics admission examination dummy variable)

Table 2: List of Variables

Annual income	Units of 10,000 yen
Age	Number of full years at the time survey was conducted
Male	Male=1, Female=0 (dummy variable)
Admission difficulty	Deviation value for admission to the relevant department/university at the time survey was conducted (2008)
Mathematics, admission examination	Sat admission examination in mathematics at any point in the admission process, including preliminary examinations and center examinations=1 Other=0 (dummy variable)
Father's higher education	Father holds bachelor degree or higher=1 Other=0 (dummy variable)
Mother's higher education	Mother holds bachelor degree or higher=1 Other=0 (dummy variable)
Science graduate	Science graduate =1, Non-science graduate=0 (dummy variable)

Table 3: Descriptive Statistics: Humanities Graduates

	Overall		All employed		Humanities C rank		Humanities B rank		Humanities A rank	
	Average value	N	Average value	N	Average value	N	Average value	N	Average value	N
Annual income (unit: 10k yen)	528.9	2152	624.7	1611	452.7	207	539.1	376	703.9	388
Age	42.57	2152	41.12	1611	38.05	207	41.02	376	42.91	388
Male	0.71	2152	0.8132	1611	0.6860	207	0.7234	376	0.7938	388
Mathematics Admission examination	0.69	2152	0.72	1611	0.43	207	0.59	376	0.68	388
Father's higher education	0.3453	2152	0.3315	1611	0.3382	207	0.3112	376	0.3892	388
Mother's higher education	0.0976	2152	0.0919	1611	0.0870	207	0.0718	376	0.1186	388
Science graduate	0.36	2152	0.40	1611						
Admission difficulty	55.43	2152	55.18	1611						

as part of their university admission exam varied considerably according to admission difficulty: 43% of graduates from C rank universities, 59% of graduates from B rank universities, and 68% of graduates from A rank universities. The mathematics admission examination dummy variable, of course, is an index signaling whether the graduate in question learned mathematics for the purpose of the admission examination, and whether or not he or she has the corresponding mathematical ability.

The results of the multiple linear regression analysis conducted in order to clarify the annual income values of humanities graduates are shown in Table **4**. The linear regression model on annual income *Y* is specified as

$$\begin{aligned} Y_i = \beta_0 + \beta_1 \text{Age}_i + \beta_2 \text{Age squared}_i + \beta_3 \text{Male dummy}_i \\ + \beta_4 \text{ Mathematics admission examination dummy}_i \\ + \beta_5 \text{Father's higher education dummy}_i \\ + \beta_6 \text{Mother's higher education dummy}_i \\ + \beta_7 \text{Science graduate dummy}_i + \beta_8 \text{Admission difficulty}_i + \varepsilon_i, \end{aligned} \quad (1)$$

where subscript i is the observation number, and ε_i is the random component.

The following three points are of particular note with regard to the findings.

Firstly, there was no significant difference in the admission examination dummy variable for graduates of C rank universities, but there was a significant positive result for graduates of B and A rank universities. From the value of the standardized coefficient, it was possible to establish that the positive impact of the admission examination dummy variable on annual income was more considerable for graduates of A rank universities than for those of B rank universities. This agrees with the findings of previous studies; that income disparity widens according to whether an A rank university graduate took a admission examination in mathematics.

Findings indicate that the higher the ranking of the university in which the respondent was enrolled, the greater the impact of the mathematics admission examination dummy variable; this results can be interpreted as follows. The higher the ranking of the university, the greater the likelihood that a graduate of that university will be able to gain employment at leading companies, and the mathematical ability acquired through mathematics learning will generate more opportunity to obtain gainful employment from a wider range of options. It will also influence steady promotion and therefore have a strong impact on income.

Secondly, an analysis of the overall sample data using dummy variables based on the respective rankings of the universities attended by the parents of respondents did not produce any significant results, for

Table 4: Estimated Results for Annual Income: Humanities Graduates

	All employed		Humanities C rank		Humanities B rank		Humanities A rank	
Adjusted R-squared	**0.263**		**0.101**		**0.311**		**0.189**	
Coefficient value	**Unstd. coef.**	**Std. coef.**	**Unstd. coef.**	**Std. coef.**	**Unstd. coef.**	**Std. coef.**	**Unstd. coef.**	**Std. coef.**
(Invariable)	-1341.602**		-559.029		-485.719		-1272.070**	
Age	48.079**	1.197	39.428	1.116	26.222*	0.795	66.542**	1.524
Age squared	-0.430**	-0.907	-0.384	-0.872	-0.175	-0.439	-0.642**	-1.285
Male	255.762**	0.256	143.616**	0.219	284.570**	0.410	313.929**	0.281
Mathematics admission examination	68.499**	0.079	8.266	0.013	67.088*	0.106	140.606**	0.145
Father's higher education	46.461*	0.056	-20.306	-0.032	50.397	0.075	41.549	0.045
Mother's higher education	41.502	0.031	9.798	0.009	-24.085	-0.020	87.761	0.063
Science graduate	70.176**	0.088						
Admission difficulty	8.192**	0.223						

Notes: *=significance level of 5%; **=significance level of 1%. Significance of standardized coefficients is identical to that of unstandardized coefficients.

either the father's or the mother's higher education dummy variable. However, results did reveal that the higher educational background dummy variable for the father had a positive impact on the income of humanities graduates at the 5% significance level.

Thirdly, the level of significance and standardized coefficient for age showed the largest positive influence on graduates of A rank universities. This implies that the greater the level of admission difficulty, the more income will increase with advancing years.

3.2. All Graduates

Here, the results of the analysis for all graduates, including science graduates, are presented. The descriptive statistics, shown in Table **5**, show that although there was little difference in age, with the average of all graduates in each category being around 40 years old, average annual income increased rapidly with university rank. Graduates of C rank universities had an average annual income of 5,308,000 yen; graduates of B rank universities an average annual

Table 5: Descriptive Statistics: All Graduates

	Overall (Identical to Table 3)		All employed (Identical to Table 3)		All graduates C rank		All graduates B rank		All graduates A rank	
	Average value	**N**	**Average value**	**N**	**Average value**	**N**	**Average value**	**N**	**Average value**	**N**
Annual income (unit: 10k yen)	528.9	2152	624.7	1611	530.8	478	597.0	595	738.8	538
Age	42.57	2152	41.12	1611	39.28	478	41.28	595	42.6	538
Male	0.71	2152	0.8132	1611	0.8305	478	0.7866	595	0.8271	538
Mathematics Admission examination	0.69	2152	0.72	1611	0.70	478	0.71	595	0.76	538
Father's higher education	0.3453	2152	0.3315	1611	0.3096	478	0.3109	595	0.3736	538
Mother's higher education	0.0976	2152	0.0919	1611	0.0795	478	0.0739	595	0.1227	538
Science graduate	0.36	2152	0.40	1611	0.57	478	0.37	595	0.28	538
Admission difficulty	55.43	2152	55.18	1611						

Table 6: Estimated Results for Annual Income: All Graduates

	All employed (Identical to Table 4)		All graduates C rank		All graduates B rank		All graduates A rank	
Adjusted R-squared	**0.263**		**0.176**		**0.276**		**0.210**	
Coefficient value	**Unstd. coef.**	**Std. coef.**	**Unstd. coef.**	**Std. coef.**	**Unstd. coef.**	**Std. coef.**	**Unstd. coef.**	**Std. coef.**
(Invariable)	-1341.602**		-451.496		-540.617*		-1545.750**	
Age	48.079**	1.197	30.163*	0.897	27.886**	0.757	76.883**	1.681
Age squared	-0.430**	-0.907	-0.246	-0.601	-0.174	-0.397	-0.741**	-1.406
Male	255.762**	0.256	176.971**	0.215	260.960**	0.305	323.173**	0.265
Mathematics admission examination	68.499**	0.079	0.627	0.001	74.201**	0.096	132.325**	0.122
Father's higher education	46.461*	0.056	17.853	0.027	36.722	0.048	94.875*	0.100
Mother's higher education	41.502	0.031	28.330	0.025	-5.704	-0.004	88.439	0.063
Science graduate	70.176**	0.088	73.473*	0.118	78.954**	0.109	53.204	0.052
Admission difficulty	8.192**	0.223						

Notes: *=significance level of 5%; **=significance level of 1%. Significance of standardized coefficients is identical to that of unstandardized coefficients.

income that was approximately 1.12 times that of C rank university graduates (5,970,000 yen); and graduates of A rank universities an average annual income that was approximately 1.39 times that of C rank university graduates (7,388,000 yen).

The results of the multiple linear regression analysis conducted in order to clarify the annual income values of all graduates are shown in Table **6**. The linear regression model is the same with equation (1). The following three points are of particular note with regard to the findings.

Firstly, the mathematics admission examination dummy variable had an increasingly positive impact on income as university rank increased. It should be noted that all of the science graduates will likely have taken admission examinations in mathematics, so this increase may well be an expression of the effect of admission examinations in mathematics on humanities graduates only.

Secondly, with regard to the higher education of graduates' parents, the higher educational background dummy variable for the father had a positive impact on the income of all graduates and of graduates in A rank universities at the 5% significance level.

Thirdly, the science dummy variable, newly introduced as an explanatory variable, had a significant positive impact on the annual income of all graduates, and C and B rank graduates[2].

3.3. Income Profile Estimates based on Experience of Mathematics Admission Examinations

Here, the income profiles of humanities and science graduates and of graduates of each rank of university are estimated in order to gain a clearer understanding of the extent to which sitting an admission examination in mathematics has an impact on income. The income function obtained in 3-2 was used to create Figure **1**, below, showing the income of male respondents at difference ages, increasing in increments of 5 years at each stage[3].

As the graph shows, the highest income average is for science graduates who studied at A rank universities. It is also clear that there is considerable disparity in average income between those humanities

[2]Of the respondents who were science graduates, around 1% (N=21) were graduates of medical departments, but there was no difference in results even when this variable was controlled. It should be noted, then, that it is not the case that the income average of science graduates is being inflated by figures from medical graduates. This disagrees with the discussion in Chapter 3 of Tachibanaki and Matsuura's 2009 publication, entitled "3: Career Success and Economic Life of Science Graduates are Unfavorable when Medical School Graduates are excluded".

[3]In order to determine how income profiles differed according to whether graduates had sat admission examinations in mathematics, it would also be possible to use an estimation model that takes into account the cross term for mathematics admission examination and age, but this cross term did not produce any significant results.

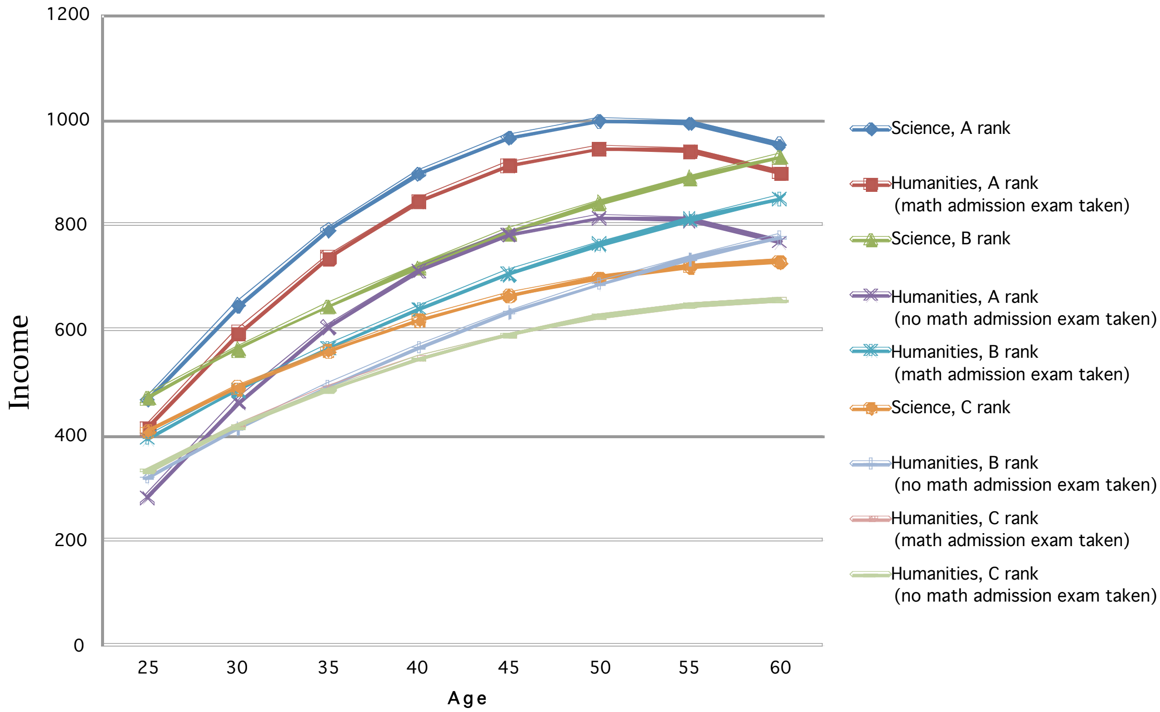

Figure 1: Income Profiles (Male Respondents).

graduates from A rank universities who did and those who did not sit an admission examination in mathematics. For graduates of C rank universities, by contrast, sitting an admission examination in mathematics did not appear to result in any disparity in average income for humanities graduates (the lines overlap on the graph), although the difference in income for humanities and science graduates is clearly discernible.

Of particular interest is the fact that a comparison of humanities graduates of A rank universities who did not sit admission examinations in mathematics with science graduates of B rank university showed that it was the science graduates who recorded higher average income at every age grade.

The above comparison also reveals that even those humanities graduates of A rank universities who did sit admission examinations in mathematics are out-earned by science graduates of B rank universities in the under 30 and 55 and over age groups.

Checking the impact of age on income for each level of admission difficulty revealed that there was a strong upward trend in income for A rank graduates until age 50, which is also the age at which income is highest over the entire working lifetime. As admission difficulty decreases, however, the income profile curve becomes proportionally shallower. The correlation between the level of admission difficulty and the steepness of income profile curve may indicate that graduates of A rank universities: more commonly take up positions of responsibility in companies as a result of promotion; and are better able to directly link such skills as good judgment and reasoning to business success, and build up this experience over the years allowing them to develop their skills further, thereby ensuring increasing success.

4. CONCLUSION

This paper was an attempt to analyze, using empirical data, the impact on income of mathematics learning, according to the admission difficulty of the universities attended by survey respondents. Of all the results, the following two points are particularly noteworthy.

Firstly, survey findings indicate that graduates of A ranked universities are employed in positions requiring considerable human capital, in which mathematical skills can function effectively. Rather than this being the result of such graduates gaining employment at large and leading companies as a result of signaling and therefore attaining higher income, these results suggest that a more credible interpretation would be that such graduates have built up a rich stock of human capital and the application of this capital has resulted in higher income. The conclusion that can be drawn here is that a high-level academic background (A rank) leads to high income because of the human capital accumulation effect, rather than because of any signaling effect.

Secondly, the fact that, overall, science graduates have a higher average income than humanities graduates indicates that the added value they are producing is higher than that of humanities graduates. This is a telling message in the face of the decline in science take-up. Furthermore, the ability to use creativity to generate new value will be the crux of competitiveness in society as it progresses in the future. The importance of human capital, therefore, will likely only increase. In this context, the need to include science-based training as a core element of academic curricula seems unquestionable.

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