広島大学　高等教育研究開発センター　大学論集
第 33 集（2002年度）2003年３月発行：127―143

Economics of Education. Part 7. Returns from R&D in Japanese Industry and Universities

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1. Introduction.

A relationship between R&D and increased productivity is well established in economic theory. Of even greater significance is recognition by government that investment in research contributes to increase of national wealth; and by industry that it generates profitability. Direct evidence for this is provided by company financial reports. Profitability of companies undertaking R&D is consistently and substantially greater than for those companies that do no research. Not surprisingly, industrial spending on R&D in Japan is high and has increased at an average rate of about 5% over the past 25 years.

Even so, commercial decisions to commit resources to R&D are accompanied by many doubts. They arise from two major areas of concern. One reflects the nature of research work. No individual research project can be guaranteed to be successful, let alone profitable within a specified period; it is only when research is reviewed on a scale sufficient to be assessed statistically that its value can be assured. The other cause for concern is the problem of identifying the level of profit attributable to research; in company accounts, only expenditure on R&D is easy to locate.

Few anxieties and no inhibitions prevent academic institutions from performing research. University staff regard the opportunity to engage in research as a principal benefit of academic employment. Government encourages and subsidises the research as an essential component of policy for economic growth. The results of academic research are normally published in journals and books to become a public good. Accordingly, while it is accepted that the research constitutes a significant economic asset, there is no direct means of assessing its value or of estimating the return it provides.

Internal estimates of profits generated by company R&D require careful analysis of costs. These are frequently obscure in multi-product organisations. The effect of R&D on overall profitability is more readily accessible through detailed time-series analysis. When aggregated across whole sectors of industry this can yield values for both private and social rates of return from investment in R&D. Analysis of data from research-intensive industries in Japan by Goto and Suzuki indicates annual social rates of return averaging 40%. Similarly Mansfield (1991, 1998) has demonstrated that it is possible to identify earnings from commercial exploitation of academic research corresponding to annual social rates of return of 28% on total academic research expenditure.

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Treatment of R&D as an accumulating non-tangible asset rather than an annual expense has been developed by Lev as the basis of a convenient approach to estimating both its magnitude and its yield. By applying this approach to a wide range of research-intensive American manufacturing industry, Lev and Sougiannis demonstrate annual private rates of return from investment in R&D in the range 15%-28%.

An abbreviated and simplified version of their method was recently used to obtain an estimate of the rate of return from R&D across industry in Japan and to apply the result to give an estimate of the value of academic research in the universities (Morgan, 2001). This result was obtained with a small and limited data set. It has now been possible to improve this procedure by the use of a more extended and comprehensive data set. Application of these results to academic research now allows estimates of its economic value, provides a basis for quantifying the scale of aggregated research knowledge in the universities, and permits examination of alternative routes for optimising its benefits.

2. Procedure.

Company earnings can be expressed as a function of tangible and intangible assets. Tangible assets (including inventory) are valued and reported in company annual financial statements. Intangible assets, apart from notional intangible fixed assets, are not reported. With the assumption that they consist largely of R&D, they can be estimated as a cumulative capital asset from annual expenditure on R&D. For a given year, R&D capital comprises the sum of the depreciated value of expenditure in the current and previous years. This can be written:

$$\text{R\&D Capital} = \Sigma\, [a_k(RD)_{t-k}]$$

where the proportion of R&D expenditure (RD) that survives productively in year t-k is summed over n years (n = 0,1...k). Then the relation between income (I) in year t to tangible and intangible assets becomes:

$$(I/S)_t = a_0 + a_1(TA/S)_{t-1} + ([a_{2k}(RD/S)_{t-k}] + e$$

where S is annual sales, TA is tangible assets, RD is expenditure on R&D in each of t-k years, a_0 is a constant, a_1 is the coefficient for tangible assets and a_{2k} is the set of coefficients corresponding to depreciation of intangible capital; e is an error term. The value of k (0, 1....n) is determined by the effective lifetime of investment in R&D. This is assumed to follow a polynomial decay and is estimated by an end-limited Almon lag procedure (Maddala).

3. Data.

No one generally accessible set of data provides all necessary information to perform this analysis. Annual statistics for R&D expenditure aggregated across sectors of Japanese industry are available in the Report on the Survey of Research and Development (R&D Report) (Statistics Bureau). This also provides some limited additional data for sales and operating profit. More extensive financial data aggregated by sector are in the Financial Statements of Principal Enterprises complied by the Bank of Japan (BoJ Statements): these data include tangible assets, inventories, sales, gross and operating profits but not R&D expenditure. The two samples are not identical. However, the composition of the sample used in the BoJ Statements (companies with capital not less than Yen 1 billion) and the data for large companies in the R&D Report (capital not less than Yen 10 billion) appear to be similar: although they vary over time, numbers of companies in the samples are similar and the ratios (operating profits/sales) in the two samples are similar and well correlated (r, 0.97). Moreover restricting analysis to the larger companies ensures that a high proportion (82%) is engaged in research in comparison with the much lower proportion (9%) of all the companies included in the whole sample for the R&D Report.

Coverage of the two data sets is not identical. The scope of the BoJ Statements is wider than that of the R&D Report, which is largely restricted to manufacturing industry. Conversely, fewer segments of manufacturing industry are explicitly identified in the BoJ data. This restricts analysis to 10 segments of manufacturing industry plus the construction industry. Further constraints are imposed by the different format of presentation of the BoJ Statements before 1980 and termination of the series in 1996, so that analysis is restricted to the 16-year period 1980-1995. Unless otherwise stated, all costs and prices are expressed in 1990 Yen.

Data on the costs of academic research are taken from Morgan (2001).

4. Results

Regression of estimates of R&D capital on earnings from sales by research-active companies across Japanese industry according to equation 2 shows a return on investment of 210%-250% over a period of 7-years at an annual rate of 20%-24% (Table 1).

Accumulation of R&D capital was assumed to conform to a symmetrical, end-limited Almon lag function. Varying the period of accumulation of capital within the range 4-10 years showed little change in the overall return. Nor were the correlation parameters clearly sensitive to the period of capital accumulation but optimal values corresponded to a period of about 7-years for effective depreciation of capital. This period is comparable to the range 5-9 years identified for depreciation of R&D capital in different sectors of industry in the USA (Lev and Sougiannis).

To reflect the direct effects of investment in R&D, earnings from sales (gross profits) were used as a measure of income: this excludes administrative expenses, taxation, depreciation and income from financial assets. Treating expenditure on R&D as capital investment rather than a production cost implies an adjustment to the stated income by adding back the costs of R&D less depreciation of R&D capital. Conversely, if R&D expenditure is booked either as a central administrative cost or as capital investment, no change is needed. The net effect, on both income (ca. 1%-2%) and on return from R&D (Table 1) is small.

Table 1. Results of Regression of R&D Capital and Tangible Assets on Earnings for Industry in Japan, 1981-1995

	1981-1995			1986-1995		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
Return on R&D Capital	211%	222%	200%	191%	201%	178%
Annual Rate of Return from R&D	22%	24%	20%	19%	21%	17%
Annual Rate of Return on Tangibles	2.0%	2.7%	6.3%	1.6%	2.2%	4.7%
R^2	0.30	0.34	0.28	0.27	0.30	0.24
t_{stat}(R&D)	8.46	9.07	7.30	6.26	6.75	5.55
t_{stat}(Tangibles)	0.78	1.08	2.02	0.49	0.70	1.23

R&D capital is depreciated over 7 years in accord with end-limited Almon lag parameters. Return from R&D capital and tangible assets is estimated from equation 2. Annual rate of return from R&D capital is given by the stream of earnings indicated by the lag parameters. In model 1, earnings are corrected for costs of investment in R&D, less depreciation; tangibles includes inventory; in model 2, no correction is applied to earnings; in model 3 earnings are corrected as in model 1 and include changes in inventory; tangibles does not include inventory.

Tangible assets were included explicitly in the correlation. Inventories were treated either as additional tangible assets, or alternatively by adjusting earnings to reflect year-by-year changes in inventory. Estimates of returns from tangible assets appear to be low, particularly in recent years; while this may well reflect trading conditions, the results have only low statistical significance.

Although the regression coefficients for the Almon lag parameters are satisfactorily significant (at the 0.05% level), the precision of the regressions was not high (R^2 *ca* 0.3) and much lower than that reported by Lev and Sougiannis. This appears to be an inevitable consequence of aggregating data across industries without allowing for the characteristic and differing lags appropriate to each sector. The errors implicit in the use of multiple sources of data will also contribute significantly to the lack of precision and might be expected to nullify any attempt to refine the procedure.

5. Discussion.

(a) Industry R&D. From their study of some 800 companies, Lev and Sougiannis obtained estimates of industry average returns from R&D capital in the range 166% (machinery)-263% (chemicals and pharmaceuticals). These returns accrue during the average lifetime of R&D capital, which varies according to the sector of industry from 5-years to 9-years. The corresponding internal rates of return, derived from the stream of earnings over these periods, lie in the range 15% (machinery) to 28% (chemicals and pharmaceuticals). In Japan, Goto and Suzuki analysed data from a range of research-intensive manufacturing industries, identifying effective lifetimes for R&D capital of 4-7 years with annual rates of return averaging 40%.

Average figures for research-active companies across all industry in Japan (Table 1), show similar results. While the high values, 20%-24% reflect the evident commercial benefits from investment in R&D, they have to be seen in an appropriate context. In terms of commercial profitability, the returns, based on income from sales, need to be adjusted to incorporate substantial charges for company overheads, depreciation and taxation. Further, because they are derived from aggregate data across all industry, they constitute quasi-social returns rather than the lower private rates of return that are generated by internal company investment in R&D. Comparison with the results of detailed studies by Odagiri and Murakami of the pharmaceutical industry in Japan (1967-1986) confirms the scale of these effects, with private rates of return from R&D of 15%-19% increasing to 20%-23% for quasi-social rates, and 30%-40% for social rates.[1)]

Commercial returns from R&D are dependent on markets and fluctuate with the level of economic activity. Estimates of returns for each year within the period 1981-95 indicate high returns in the peak growth years of the 1980's, low returns in 1992-94, and an increase in 1995. Standard deviations of returns (0.6-0.7) about the overall mean values for the period 1981-95 reflect the scale of these fluctuations. However, because of the lag in returns from investment in R&D, annual values have limited significance: moving average returns for extended periods offer more relevant results. Comparison of the average returns for the 10-year periods 1981-1990 and 1986-1995 does show the expected reduction but indicates that returns remain substantial.

(b) Academic R&D. The success in assessing commercial returns (i.e. output) on the basis of investment (i.e. input) suggests that, despite its conceptual limitation, the procedure might be extended to non-commercial R&D. The status of academic research as a public good excludes the possibility of identifying income generated directly from it.[2)] However, information on financial input is available (Morgan, 2001). By following the procedure used for industry, the R&D capital, accumulated in the university system in Japan is estimated to be (1995) ¥4,345 billion.[3)] An annual return on this capital at an average commercial rate of 20% would amount to ¥869 billion.

There is of course little evidence of financial return to universities from their research. The academic tradition, placing university research in the public domain, by definition reduces the incentive for commercial exploitation by universities. Current encouragement to protect intellectual property rights by patenting research results would have the effect of identifying some academic research as a private good. Explicit financial gain from this will need to be set against the potential erosion of the basis for public subsidy of academic research as a non-excludable good and the actual loss of accompanying academic benefits. Even so, in the US, where with the Bayh-Dole Act the economic environment favours academic entrepreneurial developments, direct financial benefit remains small: two-thirds of research income is provided by government and less than 1% is provided by license and royalty payments[4)] (N.S.F). There is though much evidence of the high economic value of university research. Mansfield showed that of new products and processes introduced commercially into the US, 10% were "dependent on"-and a further 7% were "very substantially facilitated by"-recent university research. With knowledge of the value over time of their sales and estimates of total expenditures on all university research, he calculated a social rate of return of 28% from these products alone. Similar results have been reported from Germany but with lower estimates of returns (Beise and Stahl). These results are further supported by an estimate of at least 16% as the social rate of return from publicly funded R&D in the US (Mamuneas).

Although economic returns appear to be similar in scale, and levels of competence and productivity for academic research at least match those in commercial research (Morgan 2001), its performance exhibits distinctive characteristics. These fall into four groups: (i) a substantial part of academic research is devoted to the humanities, social sciences and the arts; (ii) a high proportion of academic research is categorized as basic research; (iii) inefficient transfer of academic research imposes substantial delay on commercial development; (iv) progress of research is impeded by the priority assigned to teaching. Each of these characteristics might be expected to reduce the economic value of academic research. The evidence suggests that, to a large extent, the converse may be true.

(i) *Subject Mix.* About one-third of university expenditure on research, and a higher proportion of academic staff, is located in faculties of humanities, social sciences and arts. Conventionally, little commercial advantage has been expected from exploitation of research in these areas. The Survey of R&D does not include data for economic activity in the service industries. From the late 1980's there has been rapid growth in the US of the proportion of industrial R&D in the service sector. It rose from 9% of all industrial R&D in 1987 to 20%-25% in the 1990's (N.S.F.). On this basis, the existing level of research in humanities, social sciences and the arts is perhaps too small to satisfy the needs of what is already the largest sector of industry in Japan and where increased productivity may provide a key to future prosperity.

(ii) *Basic Research.* For statistical purposes, expenditure on R&D is categorised as 'basic' or 'applied' research and development. Most expenditure in industry is on development (72%) and least on basic research (7%). Conversely in universities basic research accounts for 52%, applied research, 47% and development 7% of research expenditure (Statistics Bureau). A commercial return is clearly dependent on the ability to provide saleable products or processes; to this end, applied research and development are essential components. Commitment of less than half of universities R&D to these aspects might suggest that it is capable of generating only lower returns. Arguments for increasing the relevance of academic research and for increasing resources available for applied research are based on this supposition. The evidence does not support it. Commercially, it is basic research that generates the higher returns (Mansfield, 1980; Link; Griliches; Lichtenberg and Siegel, Funk). This apparently perverse result is attributable to two factors. First is the advantage provided by access to new discovery; this is limited by rapid diffusion and "spillover" of new knowledge. Low commercial investment in basic research is a consequence of the inability to retain the full benefit of new discoveries within a company. By the same token, "spillover" has economic advantage by allowing other companies to benefit; their ability to do so provides the second factor, absorptive capacity (Levin; Bernstein; Cohen and Leventhall). An ability to assimilate new knowledge requires a familiarity with emerging techniques and concepts, most effectively available through participation in basic research. The implication is that universities are particularly well placed to benefit from both of these factors and generate high value research. Indeed it is perhaps a defect that the proportion of basic research in Japanese universities (52%) is substantially lower than that in US universities (69%) (N.S.F.).

(iii) *Delayed Transfer.* The traditional means of placing university research in the public domain is through academic journals. Although electronic and personal communications provide faster alternatives, delays in publishing results are endemic. Together with additional delays in recognition of the significance of results they impose time penalties in the process of developing commercial products. Estimates of delays between availability of research results and receipt of a commercial return vary up to 7 years (Mansfield, 1991). In effect this constitutes a lag in obtaining a return from capital invested in academic research without any increase in the value of the return. To estimate the scale of the consequent reduced rate of return, two models have been examined: (a) a simple extension of the time over which research capital accumulates, appropriate for a situation where research continues during commercial exploitation; and alternatively (b) retention of the 7-year lag time applicable to commercial research but introducing a delay period before commercial returns become available. For both models, the overall return is held at the level established for commercial research. With an arbitrary assumption of 12 years as the total period for both models the rates of return are effectively halved (Table 2). Even so, at these levels the returns remain comparable to those indicated for returns from R&D in the public sector in the US (Mamuneas) and substantially greater than those expected from other public investments in Japan.

Table 2. Effects of Academic Delay on Rate of Return from University Research Capital in Japan

1981-1995	Model 1		Model 3	
Return on R&D Capital	211%		201%	
Commercial Rate of return	22%		20%	
Academic Delay	12 Year lag	5 Year delay, 7 Year lag	12 Year lag	5 Year delay, 7 Year lag
Rate of return on Academic R&D Capital	13%	9%	12%	8%

Model 1 and model 3 are as defined in Table 1. Total returns on capital are unchanged but the earnings stream is extended to 12 years, either by using lag parameters for a period of 12 years, or by assuming zero returns for an initial period of 5 years followed by the stream of earnings indicated by the parameters for a 7 year lag.

Notional returns of 8%-13% from accumulated academic research capital depreciated over 12 years would have amounted to ¥700-¥1,1000 billion in 1995, that is, more than the annual subsidy provided from government revenue.

(iv) *Teaching.* Progress in research is frequently slower than is either planned or might have been hoped. Often this is a consequence of problems whose solutions provide unexpected benefits. It is though common to suggest that slow progress and delay in academic research is due either to a priority assigned to teaching or to an intrinsic lack of urgency. Academic staff in Japanese universities spend half their time on research, a higher proportion than is achieved in US or European universities. Moreover, this high average is sustained in an average working week longer than that worked in industry, or by university graduates in other employment. Measured by research output, academic staff are more productive than those employed full-time on research either in research institutes or in industry (Morgan, 1999, 2001). The importance attached to priority of discovery by the academic community provides its own urgency, irrespective of the financial or economic benefits that it may confer. Yet it is arguable that the economy would be better served if a greater proportion of time were required by teaching, and in particular, by teaching graduate students. Subsequent employment of graduate students provides the most effective means for diffusion of new knowledge (see e.g. Schuetze and Fujitsuka). It is the balance between advanced study and research that equips graduate students for this function. Through teaching they become informed of current development and the codified knowledge of published material; in their research they are trained and become familiar with the tacit knowledge of techniques and skills. (Dasgupta and David) Together these two components allow graduate students proceeding to employment in industry to transfer the full range of benefits available from participation in basic research. Transfer of benefits in this way does not involve any significant "academic delay" and should be expected to yield an unattenuated rate of return. To the extent that graduate students are able to transfer the full value of academic research—containing a large proportion of high-value basic research—it should generate a rate of return at least equivalent to that available from commercial R&D.

(c) Location of Research Capital. An inability to touch an intangible asset does not imply that it has no physical location. Companies hold a variety of intangible assets in the form of documents. Research capital may appear as patents, licences, research reports and published articles. But clearly, research capital resides primarily in the research staff, who retain knowledge of the results they generate. Moreover, because research capital exists as knowledge, dissemination of research results increases rather than diminishes the total value of the capital even though it may substitute social for private return.

In universities, many people contribute to the progress of research and acquire research knowledge. It would though be appropriate to regard academic research capital as embodied in the senior academic staff *i.e.* professors, associate and assistant professors, and lecturers. Averaged over the total number of these staff in the whole university system, the research capital held by each of them would have amounted to (1995) Y 44.8 million.

Distribution of research capital varies within the system with respect to the university sector and the

Table 3. Academic R&D Capital per Member of Academic Staff, Japan (1995)

¥ million (1990)

	National Universities	Public Universities	Private Universities	All Universities
Social Science & Humanities	23.08	22.30	36.74	33.21
Science & Engineering	70.25	47.09	43.06	57.61
Medicine	84.65	62.60	65.24	71.60
Other Areas	19.91	21.14	32.49	26.01
All Subject Areas	50.02	37.52	42.12	44.84

Academic Staff includes professors, associate and assistant professors and lecturers as listed in the Schools Basic Yearbook (MESSC).
Science and Engineering includes Agriculture; Medicine includes other Health Sciences; the largest single component of "Other Areas" is Education.
R&D capital is depreciated over 7 years. Figures are recalculated from data used for estimates in Morgan (2001).

subject area. By using the previously reported data it is possible to derive the distribution of capital shown in Table 3. These figures reflect the much higher levels of research capital committed to agriculture, engineering, science and medicine; they also indicate the strength of investment in research in the national universities in these areas.

(d) Dividends from Research Capital. For commercial companies return on research capital appears as revenue from sales. Over time, the estimated average return across all research-active industry is indicated to be 20%-24%. Lev and Sougiannis showed that for US industry returns varied substantially amongst the various sectors of industry; and as was shown by Mansfield, these returns will draw significantly on research originating in universities. Explicitly, these returns derive from new and improved products and processes; implicitly they are dependent on the skills and expertise of research workers, and notably on the knowledge of developments in basic research brought by recent graduate students.

University research, leading directly to products and processes, is similarly expected to generate returns, attenuated by the extended lag implicit in academic research at a lower rate of 8%-13%. Some of these returns will actually appear in the results of commercial companies that have developed products and processes from research placed in the public domain rather than as payments to universities or to government agencies holding licences. However, this accounts for only a small part of university research. The vast majority resides in academic staff in the form of new ideas and new techniques, disseminated through publication, personal contact and the employment of graduate students. The non-rivalous nature of this knowledge means that its value also remains fully accessible within the universities. This suggests that it may be possible to estimate internal dividends available from university research capital.

Table 4. Accumulated Research Knowledge Dividends for Masters and Doctoral Students at Graduation, Japan 1995

¥ million (1990)

Masters Graduates	National Universities	Public Universities	Private universities	All Universities
Social Sci & Humanities	7.81	7.94	12.43	10.78
Science and Engineering	23.76	15.93	14.56	20.92
Medicine	28.63	21.17	22.09	25.02
Other Areas	6.73	7.15	10.91	7.83
Total	19.69	13.21	13.88	17.41
Doctoral Graduates				
Social Sci & Humanities	13.48	13.01	21.44	17.68
Science and Engineering	40.98	27.48	25.12	38.73
Medicine	45.56	33.69	35.12	41.40
Other Areas	11.61	12.34	18.81	12.66
Total	37.79	27.49	27.87	34.71

Knowledge dividends are estimated at an annual rate of 20% of research capital embodied in academic staff. It is assumed that the value of dividends depreciates at the same rate as research capital (i.e. over 7 years). Master's students are assumed to complete studies in 2 years, doctoral students in 5 (2 + 3) years, except medicine where completion requires 4 years.

Annual dividends generated from university research capital embodied in academic staff are available to their graduate students and research assistants in the form of codified and tacit knowledge. These knowledge dividends will not be attenuated by any academic time delay and so may be assumed to achieve internally a rate of return similar to the commercial rate (i.e. 20%-24%). Moreover, as "knowledge" it is accessible equally to each graduate student and assistant.

On completion of their studies, employment allows graduate students to bring their research knowledge into the community. Its extent can be equated to the depreciated cumulative aggregate of the research knowledge dividends received by a graduate student during the period of study (Table 4). It constitutes a significant asset. While in principle the codified part of their knowledge will become available in the public domain, acquisition and application of it is not a free good but requires tacit knowledge. To obtain this knowledge, an employer would have needed to invest in research on a scale similar to that indicated by the level of professorial research capital.

An indication of the scale of transfer of research knowledge that is potentially available by this route is provided by the numbers of new graduates (1996, masters, 47,747; doctors, 8,968) and the research knowledge they had accumulated as dividends from their studies. After making allowance for depreciation in the usual way, the equivalent financial value would amount to Y 1,143 billion, representing an annual return of 26% on universities' research capital. Realising returns at this level would though be dependent on effective use of the research knowledge. A prime criterion for this might reasonably be identified with employment. Currently, only about 70% of new graduates enter employment immediately after graduation (MESSC.)[5]. Although the proportion will increase over time, this may be only after their research knowledge has significantly depreciated.

When the aggregate value of research knowledge provided by new graduates is adjusted for the numbers in employment the total financial equivalent is reduced to Y 840 billion, corresponding to an annual yield of 19%. Analysis according to subject area and university sector of graduates then reveals some striking differences (Table 5). The total value reflects the numbers of newly employed graduates and the academic research capital generating knowledge dividends. Within subject areas it is proportional to the average number of graduate students (masters and doctors) per senior member of academic staff (postgraduate student /staff ratio, pgs/s ratio): a pgs/s ratio greater than 1 increases the total dividend yield. Returns from engineering and science are very high, reflecting high employment of the graduates (79%) and a high pgs /s ratio (3.2). In contrast humanities and social sciences have low employment (21%) and a low pgs/s ratio (1.1) and consequently generate low returns; the figures for "other areas" are also low (56%; 0.9) as are the returns. For medicine, high employment (76%) is balanced by a low pgs/s ratio (1.3) to yield an intermediate level of return.

An overall annual return of 19% on academic research capital through graduate transmission indicates the importance of this mechanism. It is noteworthy that three-quarters of this comes from the national universities and two-thirds of it from the areas of engineering, science and medicine in the national universities. But the most significant aspect is that transfer of basic research knowledge from these areas

Table 5. Aggregate Transfer of Academic Research Dividends through Newly Employed Higher Degree Graduates, Japan 1995

¥ billions

	National Universities	Public Universities	Private Universities	All Universities
Social Sci & Humanities	12.6 *9%*	2.2 *6%*	36.2 *4%*	51.1 *5%*
Science & Engineering	489.4 *48%*	15.3 *22%*	109.5 *22%*	614.3 *39%*
Medicine	87.9 *19%*	9.1 *12%*	41.0 *7%*	137.9 *12%*
Other Areas	18.7 *9%*	1.0 *5%*	11.1 *3%*	33.6 *6%*
Totals	614.3	27.7	197.8	836.8
Return on Research Capital	33.5%	13.0%	8.6%	19.3%

Aggregate research dividends are obtained by multiplying the per capita values (Table 4) by the number of graduates entering employment. Aggregate research capital is given by multiplying the per capita figures (Table 3) by the numbers of academic staff. Annual returns on academic research capital are estimated by dividing the aggregate transferred research dividends by aggregate research capital; the results are shown as percentages (in italics).

appears to be potentially economically efficient. This allows a number of conclusions to be drawn that might form a basis for future research policy.

1. In the areas of science, engineering and agriculture and, to a lesser extent, medicine, the universities might be encouraged to emphasise their core competences in basic research and research training of graduate students. Any diversion of emphasis into entrepreneurial activities, which could diminish the value of research training and transmission of knowledge, might well prove counterproductive.
2. Core competence in industry lies in applied research and development and in marketing. Employers should be encouraged to exploit the research knowledge available through recruitment of new postgraduates. High rates of employment of science, engineering, agriculture and medical graduates indicate some awareness of their value. However, less than adequate appreciation of their full value appears to be indicated by failure to pay the salary premiums found in other research-based economies.
3. Low returns in the areas of humanities, social science and "other areas" clearly derive from inefficient transfer of pg research knowledge. Three factors contribute. (a) Low employment prospects for postgraduates reflect a perception that research skills and attitudes are inappropriate to the needs of industry and commerce. (b) Relatively low enrolment of graduate students corresponds to limited career opportunities. A high proportion of pg students in these areas aspires to academic employment. (c) The labour component of academic R&D capital in these areas may be over-estimated. Particularly in the private university sector, where two-thirds of all senior academic staff work in these areas, only 40% of them are identified as graduate school teachers (MESSC). While increasing demand for commercially relevant pg programmes will modify attitudes and opportunities, teaching rather than research may come to provide a more effective route to knowledge transfer through pg students. Given that demand requires extensive employment of academic staff, and that non-labour expenditure on research in these areas is low, there is little economic advantage in seeking either to concentrate or restrict the accompanying research activity. In this case it appears appropriate to accept the traditional route of transmission of research through publication in books and journals as an economically effective route
4. Responsibility for realising the potential benefits from academic research rests primarily with industry and commerce. It should though be a matter of enlightened self-interest for universities to contribute to this process. Universities might be encouraged to seek more effective links with commercial companies. Professional post-experience courses and consultancy services provide valuable opportunities for education, technical interchange and collaboration.

Notes

1) A return on commercial R&D of 20%-24% may be compared with the historic returns on capital of 12.8%-14.9% over the period 1980-1997 for the whole business sector in Japan (OECD).

2）There is a trivial argument indicating a return of 100% through the recurrent annual subsidies attracted by academic research.

3）Annual investment in academic research is taken as the sum of expenditure on research labour, consumables, equipment, and other costs and depreciated over 7 years. Inclusion of expenditure on property (land and buildings) would add an additional 9% to the total capital for 1995.

4）Royalty payments provided $675 million (1999) to US universities. Although this is a substantial sum it represents only 2.5% of designated research expenditure. Inclusion of costs of academic salaries in the costs of research reduces the proportion to 1.1%. Apart from $150 million designated for research, there is no indication how much of this income supports university research (N.S.F.).

5）Offiicial estimates of numbers of graduates entering employment assume that those with unknown status are unemployed (MESSC). An alternative assumption, that those of unknown status are distributed in proportion to those of known staus is used here. This increases the overall estimates of those employed by 4% (masters) and 8% (doctors) to 70.2% and 70.9% (1996) respectively.

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教育経済学（パート７）

―日本の産学界における研究開発からの収益―

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研究開発に対する支出を，蓄積した無形資産への投資として扱うことによって，研究開発活動が創出する利益を積算することが可能である。日本の産業界における商業ベースの研究開発にとって，毎年の収益率はおよそ20％から24％であると示されている。そして，大学における研究開発からもたらされる潜在的な収益率も同レベルにあると推計することができる。しかし，産業への知識の移転が長期にわたって遅れてきたために，大学における研究開発の直接利用から得られる毎年の収益率は 8―13％へと減少している。より効率的に知識の移転が行われれば，さらに高い利益を得ることができる。大学院生が課程修了時に産業界および商業界によって雇用されれば，大学から知を移転させる効率的なメカニズムが提供されることになる。この方法によって，大学における研究開発からの潜在的な収益率全体は19％に上がり，とりわけエンジニアリングや自然科学の分野では相当に高くなる。国立大学は学術研究が潜在的にもつ高い収益性に対して中心的な役割を果たしており，それは選択性の高い研究支援や大学院の規模といった複合的な要素に由来するものであることが示されている。国立大学が財源を基礎研究から応用研究へと比重を移すべきだといういかなる提案も逆効果になる可能性をはらんでいる。

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