The Rate of Return to New Zealand Research and Development Investment

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Foreword

Dr Robin Johnson has had a long involvement with agricultural economics in New Zealand, and with the Ministry of Agriculture and Fisheries, in particular. Although now retired, he retains an active research interest.

The results of this research were first presented to the 1999 Conference of the New Zealand Association of Economists as a report on a piece of new research. Since the subject of national productivity is of basic importance to the agricultural sector, MAF Policy is pleased to be able to publish the full paper and a new technical appendix.

The reorganisation of Government research activities in New Zealand in the early 1990s was aimed at greater efficiencies in the research provider system and greater accountability to users of research. The reforms brought out the different roles of the private and public research sectors. The private sector funds and provides research that may be of immediate benefit to firms in the business sector. The Government sector is committed to funding and providing research for the economy as a whole. The reforms sought to make this distinction transparent and were the basis for additional government funding through the Foundation for Research, Science and Technology.

This paper investigates the likely rates of return to private and government R&D funding in the productive sectors of the economy since 1962. The study employs national income statistics to derive indices of total factor productivity (TFP) for each sector. These indices show how much growth of national income (GDP) in a sector has surpassed the growth of real labour and capital inputs. In turn, it is a statistical exercise, as reported in this paper, to relate TFP to past investment in R&D.

The results indicate that private sector R&D tends to show higher and more positive returns than public R&D across all sectors. The agricultural sector appears to be particularly responsive to private R&D, but has a negative return to public R&D. The latter may represent either an over-investment or under-utilisation of R&D or both. The opposite is the case for the forestry sector which has much longer leads and lags in the investment process.

The paper points out that having established a comprehensive database of R&D in New Zealand, more research can profitably be undertaken. MAF Policy would like to encourage and be associated with such research in the future.

Alan Walker
Director, Policy, Information and Regions

The Rate of Return to New Zealand Research and Development Investment [1]

by Robin Johnson

There has been considerable debate in recent years about the relative merits of private and public research and development (R&D) investment in New Zealand. There has been a distinct lack of measurement in this area. This paper reports work on formulating a data set on past investment in R&D and results of econometric measurement of the respective rates of return. Results are available for the agriculture, fishing, forestry, processing, manufacturing, energy, building, transport and service sectors as well as the total market sector. The results indicate low rates of return to public investment in R&D and promising rates of return to private R&D in some individual sectors. There are positive responses to off-shore supplies of R&D and the level of educational investment in New Zealand in some sectors.

Introduction

The level of research and development (R&D) investment in New Zealand has been dominated by Government investment for many years. In the 1980s reforms of science providers, the issue was identified as one of "crowding out" of the private sector (NZIER 1987). In the reform process, bidding was introduced for government science funds, research departments were converted to stand-alone research institutes, and a national agenda of priorities was drawn up. Implicit in the reforms was the view that public expenditure had invaded many areas where private participation was more appropriate.

This view of the science industry was based on detailed qualitative analysis of past and present research results and current views of appropriate governance mechanisms for public research. There was no comprehensive research into the issues of relative rates of return to the respective types of R&D due to the lack of a comprehensive database. There had been some detailed sector studies which showed surprisingly high rates of return (Dick *et al* 1967, Scobie and Eveleens 1986). The particular problem was a lack of information on research expenditure in the private sector and to a lesser extent, in the universities. This was ultimately remedied in the Ministry of Research, Science and Technology (MoRST) surveys which commenced in 1989 (MoRST var).

Therefore, this paper sets out the results of a project to estimate R&D expenditure for the public sector, the private sector and the universities back to 1962. With this information available, a rate of return model was developed using sectoral productivity indices from the Victoria University Project on Planning files (Philpott 1994, 1995, 1999), and measures of public and private R&D stocks derived from the above expenditure data set. In addition, explanatory variables representing off-shore stocks of R&D and educational investment in New Zealand were included.

The paper starts with a discussion of the construction of the R&D data base, then the theoretical model employed for the estimation equations. These are followed by tables showing the econometric results and a discussion of their implications. An appendix sets out some alternative econometric specifications which were explored.

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[1] An earlier version of this paper was first presented to the New Zealand Association of Economists Conference in Rotorua, New Zealand, July 1999. Computing assistance was provided by the Ministry of Agriculture with the help of R. Forbes.

Building the Data Set

Since 1989, MoRST have carried out annual or semi-annual surveys of R&D expenditure in New Zealand (MoRST var). These carefully delineate research expenditure in the major providers of research, government, firms and universities, and also identify which productive sectors the research is aimed at. The surveys also carefully differentiate between *funding* functions and *provider* functions. Thus for the period 1989-90 to 1995-96 there is a detailed record of research expenditure on a provider and a funder basis including the designated sectors to which the research was directed. It is the *provider* basis which is adopted in this paper. Survey data for 1997-98 became available after the results reported here were completed.

For the period back to 1962, the record of Government expenditure is almost complete. Total departmental funding is faithfully recorded in the Department of Statistics' Yearbooks and designated areas of research are identified on a broad basis. Some extrapolation of data was required to get sectoral expenditure back to 1962 on a consistent basis.

In combination with the productive sectors recognised in the MoRST surveys, these Yearbook records determined the number of sectors which could be analysed for the whole period of the analysis. As the productivity data is presented on a national accounting basis (SNA), the following schema shows the sectoral allocation possible:

Research sector	**SNA sector**
Agriculture	Agriculture
Fishing	Fishing
Forestry	Forestry
Processing	Food, Wood, Paper,Textiles
Manufacturing	Mining, Basic Metal, Chemicals, Non-Metallics, Machinery
Energy	Electricity, Gas and Water
Building	Building and Construction
Transport	Transport and Storage
Services	Trade, Communications, Finance, Community Services
Total Market	Production sector (Ownership of Occupied Dwellings and Government are excluded)

For total private R&D expenditure in the years before 1989, the ratio of private R&D to government R&D in 1989 was extrapolated back to 1962 as a percentage of GDP. Since Government expenditure as a percentage of GDP in the 1970s was rising, the same proportions were applied to private expenditure[2]. Sectoral private expenditure was established for the years 1962-88 from the proportions in the 1989 survey. There is also evidence from the Manufacturers Federation (Manfed) surveys in the 1980s and the Science and Technology Advisory Committee reports (ManFed 1984, 1987; STAC 1988).

For university expenditure on R&D back to 1962, a fixed proportion of Vote Education "expenditure on university education" was used (data from the Yearbooks). From the period 1989-96 it was established that 30 per cent of the bulk grant could be roughly identified as being used for research purposes in the time of university staff[3]. This is a fairly rough measure but is reasonably consistent over the time period concerned as it is based on published data back to the 1960s. University research was allocated to sectors in proportion to Government expenditure.

Total expenditure on R&D was then deflated by the GDP implicit deflator to obtain real R&D expenditure as shown in Table 1. The choice of the GDP deflator was based on the high labour

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[2] Subsequent researchers should not go looking for complementarities between government and private R&D in the data, as it is already built in!

[3] I am indebted to Pam Maizir (MoRST) for this suggestion.

component of expenditure on R&D[4]. For the purposes of later calculations, government and university real expenditures as providers were combined into real "public" expenditure.

Table 1: Investment in R&D in New Zealand (1962-98 $m)

Year	Private Sector	Governm't Sector	University Sector	Deflator 82-83=1000	Private Investm't	Public Investm't	Total Investm't
1962	4.3	7.6	2.6	168	25.6	60.7	86.3
1963	4.4	8	2.8	177	24.9	61.0	85.9
1964	5.1	8.7	3.1	182	28.0	64.8	92.9
1965	5.9	10.5	3.4	185	31.9	75.1	107.0
1966	6.8	12	4.1	191	35.6	84.3	119.9
1967	7.9	14.2	4.8	192	41.1	99.0	140.1
1968	8.7	15.7	5.8	202	43.1	106.4	149.5
1969	9.7	17.1	6.7	210	46.2	113.3	159.5
1970	10.8	19.9	7.7	221	48.9	124.9	173.8
1971	12.8	23.1	9.8	242	52.9	136.0	188.8
1972	15.8	28.1	13.1	278	56.8	148.2	205.0
1973	19.1	33.9	17.8	307	62.2	168.4	230.6
1974	22.1	39.7	24.1	333	66.4	191.6	258.0
1975	27.4	49.4	27.6	353	77.6	218.1	295.8
1976	31.7	58.1	31.8	402	78.9	223.6	302.5
1977	34.1	62.7	30.2	486	70.2	191.2	261.3
1978	40.4	74.1	34.1	523	77.2	206.9	284.1
1979	50.9	92.4	41.2	591	86.1	226.1	312.2
1980	59.4	103.8	38.1	673	88.3	210.8	299.1
1981	71.6	128.3	47.1	774	92.5	226.6	319.1
1982	92.4	163.5	55.5	894	103.4	245.0	348.3
1983	104.1	184.5	59.9	1000	104.1	244.4	348.5
1984	115.1	187.9	61.6	1080	106.6	231.0	337.6
1985	130.4	197.1	64.1	1164	112.0	224.4	336.4
1986	145.4	230.7	84.7	1329	109.4	237.3	346.7
1987	176.3	226.1	105.2	1572	112.2	210.8	322.9
1988	191.7	249.4	113.9	1763	108.7	206.1	314.8
1989	199.2	259.1	137.9	1910	104.3	207.9	312.1
1990	217.2	290.2	139.2	2017	107.7	212.9	320.6
1991	217.1	318.2	166.3	2069	104.9	234.2	339.1
1992	222.7	317.2	177.1	2096	106.3	235.8	342.1
1993	229.2	312.4	232.4	2136	107.3	255.1	362.4
1994	263.3	343.4	233.5	2178	120.9	264.9	385.8
1995	257.1	358.1	254.1	2214	116.1	276.5	392.6
1996	252.5	375.6	273.5	2258	111.8	287.5	399.3
1997	263.4	395.1	282.2	2287	115.2	296.2	411.3
1998	271.7	407.9	291.2	2308	117.7	302.9	420.6

Sources: See text

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[4] I am indebted to Bryan Philpott for this suggestion.

The Production Function Approach to the Rate of Return on R&D

The aim is to estimate the contribution of R&D to economic growth by calculating multi-factor productivity in a growth accounting framework, and then econometrically estimating how much of the multi-factor productivity can be explained by knowledge stocks, while controlling for other possible influences on measured productivity (Industry Commission 1995). Another way is by econometrically estimating a production function directly, in which output is a function of labour, capital, the stock of knowledge capital and some additional variable.

The two approaches are related. Both can be derived from a production function of the form:

$$Y = A\, K^{a}\, L^{b}, \qquad (1)$$

where Y is output:
A is productivity;
K is the stock of physical capital; and
L is labour.

If productivity can be explained by the stock of knowledge capital and other factors, then equation (1) can be rewritten as:

$$Y = K^{a}\, L^{b}\, R^{g}\, Z^{s}, \qquad (2)$$

where R is the stock of knowledge capital; and
Z is other factors affecting measured productivity.

In the production function approach, a log linear version of equation (2) is estimated directly:

$$\ln Y = a \ln K + b \ln L + g \ln R + s \ln Z, \qquad (3)$$

with no further restrictions placed upon the parameters. The estimate of g would provide a direct estimate of the percentage increase in output obtainable from a one per cent increase in knowledge stocks, holding all other factors constant.

In the two-step productivity approach, equation (3) would be rewritten as :

$$\ln Y - a \ln K - b \ln L = g \ln R + s \ln Z \qquad (4)$$

Under the additional assumptions that $a + b = 1$ and that a and b equal capital and labour income shares, the left-hand side of (4) equals multi-factor productivity (in level, not growth form), as conventionally measured in a growth accounting framework. Observations on multi-factor productivity can then be regressed on the variables shown on the RHS.

In either case, estimates of the parameter g can be converted from an elasticity to an overall rate of return dY/dR as given by:

$$dY/dR = g\,(Y/R).^{5} \qquad (5)$$

The capital variable K is derived from capital expenditure data by the perpetual inventory method:

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[5] This is not equivalent to the internal rate of return. The IRR would need to be estimated from the long term responses in productivity. See appendix note.

$$K_t = (1 - f)\, K_{t-1} + E_{t-1} \qquad (6)$$

where K_t = the stock of conventional capital at the beginning of period t in constant prices;
K_{t-1} = the stock of capital at the beginning of period t-1;
E_{t-1} = capital expenditure during period t-1 in constant prices; and
f = the depreciation or obsolescence rate of capital.

In this study, Philpott's data on capital employed in different sectors is employed. Philpott does not use diminishing balance depreciation rates but substitutes a formula taking in the average life of assets (Philpott 1994). These estimates of the capital employed are about 50 per cent greater than those determined by book depreciation methods (Philpott 1995).

The perpetual inventory method is also applied to the R&D variables. The expenditures shown in Table 1 are treated the same as in equation (6). Knowledge is regarded as a stock of available technologies which can be added to and subtracted from. The reduction process can be treated as the depreciation factor. The initial stock of knowledge has to be established from the available data by a formula of the kind:

$$S_o = E_o / (e - f)\,, \qquad (7)$$

where S_o = the stock of R&D capital at the beginning of the first year for which expenditure data is available;
E_o = the annual expenditure on R&D (in constant prices) during the first year;
e = the average annual logarithmic growth of R&D expenditures for the nearest relevant years; and
f = the depreciation or obsolescence rate of knowledge.

The assumption is that if the stock had been growing *before* the first year at a certain rate, then the estimate of the total starting stock will be that much higher than it would have been if expenditure were capitalised by the rate of depreciation alone. In the estimates used in this paper *e* was estimated for the first ten years after 1962, and *f* was set at 5 per cent per year. Thus the starting stock for the market sector is:

$$\mathrm{S_o} = \$86.3\mathrm{m} / (0.1 + 0.05) \qquad (8)$$

$$= \$575.3\mathrm{m}\ (\text{in } \$1982\text{-}83)$$

The choice of a rate of depreciation of a knowledge stock is a difficult question. It seems clear that new inventions and ways of doing things *replace* older inventions and ways. The stock is thus a moving entity - constantly wasted and constantly replenished. Evidence is lacking on what is the appropriate course of action. Scobie and Eveleens (1986) note that "average research results are slowly incorporated into practice and their impact on productivity increases [in agriculture] reaching a peak after 11 years, and finally tailing off after a total of 23 years". This suggest a "life" of research of about 20 years with the maximum effect in the mid years of that period. Thus a rate of 5-10 per cent might be quite appropriate for a country like New Zealand - the results presented here are calculated at 5 per cent (this is discussed further in the technical appendix).

The resulting calculations at the national level are shown in Table 2. These numbers represent the notional capital stocks of R&D knowledge in real terms available to producers and firms who might benefit from their availability. In the New Zealand case, the stocks are largely public goods in the economic sense, freely available to anyone and not subject to diminishment if used by others. What is called "private" stock here is that generated by the private sector *in situ* rather than any privately held stock of knowledge in a legal sense.

Table 2: Real Estimates of R&D Stocks in New Zealand 1961-98 $82-83m

Year	Private	Public	Total	Year	Private	Public	Total
end 1961	170.6	404.7	575.3	1980	816.9	2123.9	2940.8
beg 1962	187.7	445.2	632.8	1981	868.5	2244.3	3112.9
1963	203.1	483.9	687.1	1982	928.4	2377.1	3305.5
1964	221.0	524.6	745.6	1983	986.1	2502.6	3305.5
1965	241.8	573.5	815.3	1984	1043.4	2608.5	3651.9
1966	265.4	629.1	894.5	1985	1103.2	2702.5	3805.7
1967	293.2	696.6	989.8	1986	1157.5	2804.7	3962.2
1968	321.6	768.2	1089.9	1987	1211.8	2875.2	4087.0
1969	351.8	843.1	1194.9	1988	1259.9	2937.5	4197.4
1970	383.0	925.9	1308.9	1989	1301.2	2998.5	4299.7
1971	416.8	1015.5	1432.3	1990	1343.8	3061.5	4405.3
1972	452.8	1112.9	1565.7	1991	1381.6	3142.6	4524.1
1973	492.3	1225.7	1718.0	1992	1418.7	3221.3	4640.0
1974	534.1	1356.0	1890.1	1993	1455.1	3315.3	4770.4
1975	585.0	1506.3	2091.3	1994	1503.2	3414.4	4917.6
1976	634.6	1654.7	2289.3	1995	1544.2	3520.2	5064.4
1977	673.0	1763.1	2436.1	1996	1578.8	3631.6	5210.4
1978	716.6	1881.8	2598.4	1997	1615.1	3746.2	5361.2
1979	766.9	2013.8	2780.7	1998	1652.0	3861.8	5513.8

Sources: see text

Productivity Performance

Productivity indices are made up from the formula in equation (4). The Total Factor Productivity Index (TFP) is the net output of an industry divided by the weighted sum of the labour and capital inputs used. In national accounting terms the ratio is:

$$TFP_i = Y_i / a_i L_i + b_i K_i \qquad (9)$$

where a_i and b_i are the average factor shares of income in nominal terms for the ith industry. For example, in the market sector as a whole the share of L is 0.60 and K is 0.40.

The actual data and factor shares from the Philpott data set are available in the form:

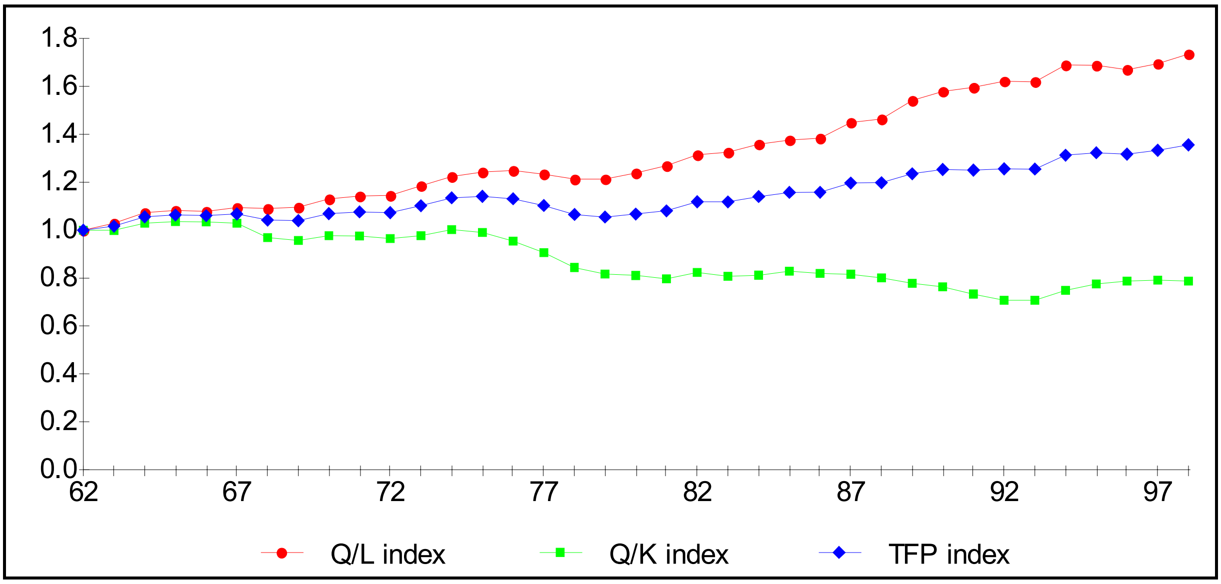
a. Real GDP by SNA Industry Group ($m in 1982-83 prices).
b. Employment in SNA Industry Groups (`000 full time equivalents).
c. Real Gross Capital Stock by SNA Industry Group ($m in 1982-83 prices).
d. Average Factor Shares in Nominal $.

The TFP index can be regarded as the weighted mean of the labour and capital productivity indices:

$$TFP_i = a_i\,(Y_i / L_i) \; + \; b_i(Y_i / K_i). \qquad (10)$$

The two components of TFP for the New Zealand market economy and the resulting TFP index are shown in Figure1.

Figure 1: Components of National Productivity



The TFP indices for each of the 9 sectors are shown in Figures 2, 3, and 4. The rates of growth for each component in each sector are shown in Table 3. Agriculture is the best performer over the period concerned followed by Energy, Transport, Forestry and Processing. Labour productivity is highest in Energy, followed by Fishing, Agriculture and Processing. Capital productivity is highest Agriculture, Energy and Forestry. It is significant that six of the sectors and the market economy as a whole had negative capital productivity.

In a recent Treasury Working Paper, Diewert and Lawrence (1999) give TFP growth estimates for the period 1978-1998 for each of the SNA industries separately. The highest is for Communications (6.77%), followed by Forestry (6.34%), Mining (4.92%) and Agriculture (3.87%). Manufacturing industries are all below 2.4%.

Figure 2: TFP for Agriculture, Fishing and Forestry

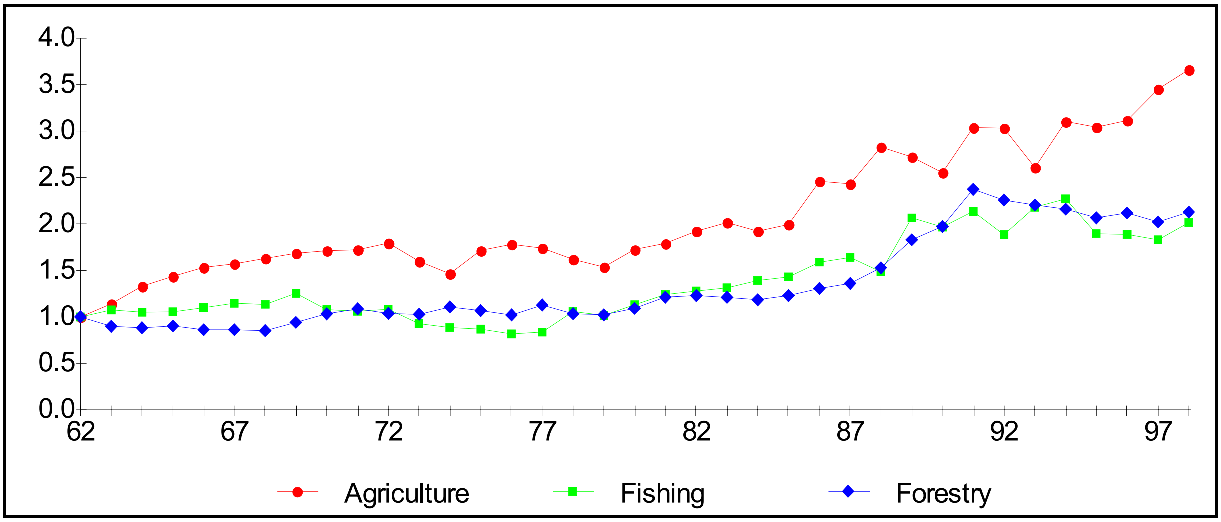


Figure 3: TFP for Primary Processing, Manufacturing and Energy

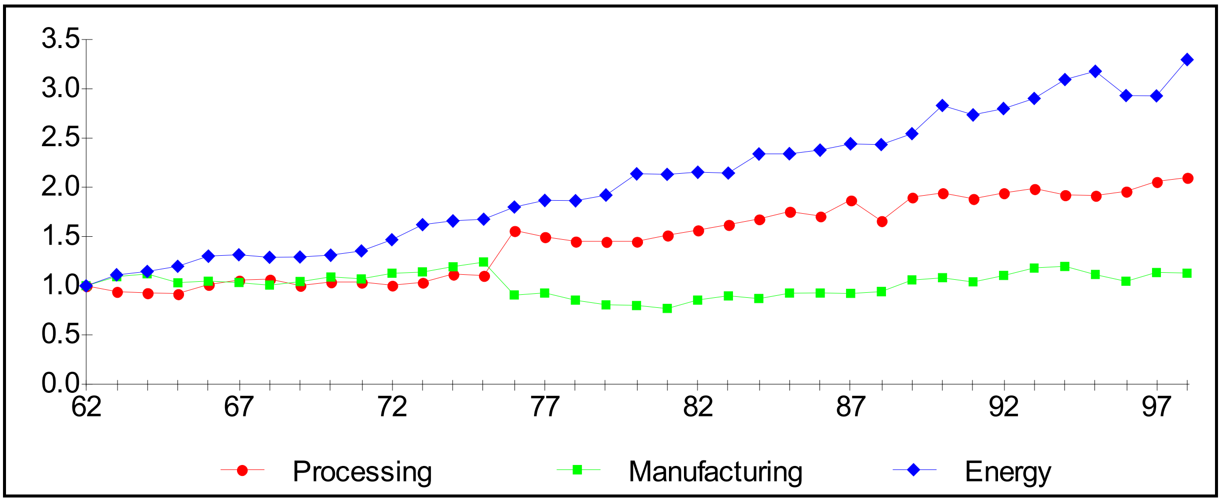


Figure 4: TFP for Building, Transport and Services

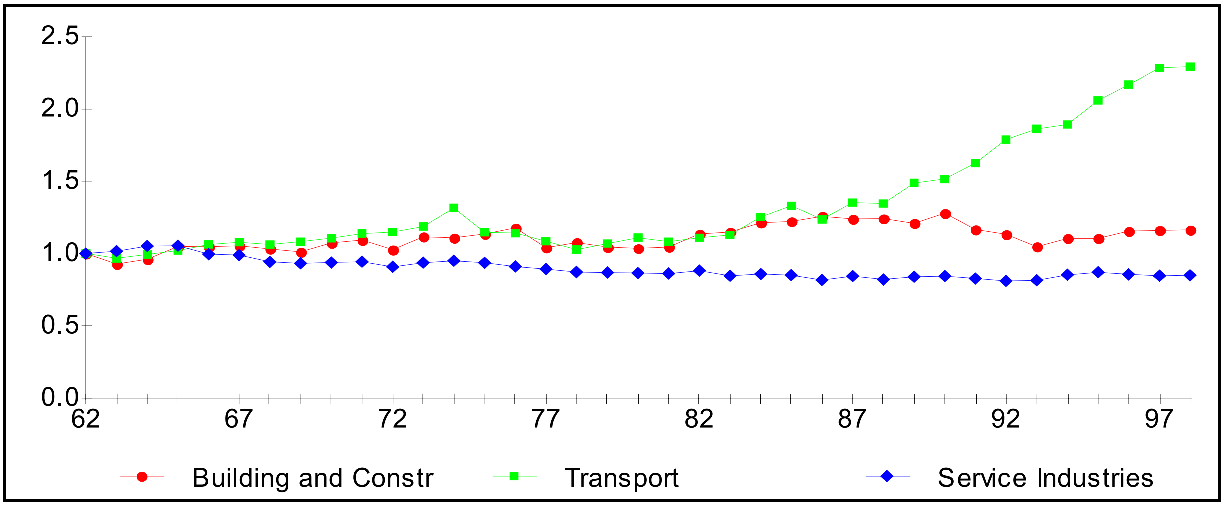


Table 3: Productivity Growth Rates 1962-1998 (% per annum)

Sector	GDP	Labour	Capital	TFP[1]
Agriculture	3.6	4.0	3.0	3.6
Fishing	5.1	4.1	-0.6	2.0
Forestry	3.5	2.1	2.2	2.1
Processing	3.1	2.8	-0.5	2.1
Manufacturing[2]	2.5	1.7	-2.9	0.3
Energy	5.0	5.4	2.0	3.4
Building & Construction	1.1	0.8	-0.1	0.4
Transport	2.8	2.9	-0.2	2.3
Services[3]	2.8	0.3	-2.3	-0.5
Market Economy[4]	2.7	1.5	-0.6	0.9

[1] Industry weights

[2] Includes Mining, Chemicals, Metals and Machinery.

[3] Includes Trade, Commerce, Finance & Communications.

[4] Excludes Ownership of Occupied Dwellings and Government Services.

Sources: Philpott 1994, 1995, 1999.

The Rate of Return to R&D

The hypothesis to be tested is that changes in sector productivity can be explained partly or wholly by changes in private and public R&D in New Zealand. To allow for other influences, the stock of Australian business R&D (Lattimore 1997, Table A2) is used as a proxy for external sources of R&D (external spillovers), and real expenditure on education in New Zealand is used as a proxy for changes in other factors. This could reflect upgrading of skills outside the physical measures of labour and capital and R&D. Thus:

$$TFP_{t\,i} = f(\,PVT\ R\&D_{t-1\ i}\,,\ PUB\ R\&D_{t-1\ i}\,,\ EXT\ R\&D_{t-1}\,,\ EDUINV_t) \quad (11)$$

Depending on tests for serial correlation, this basic hypothesis is used throughout the analysis. Some preliminary analysis was also explored that searched for spillover relationships between own-industry R&D and other-industry R&D. In the complementary case, firms get more effect by using both types of R&D together than using them on their own. In the substitution case, the multiplicative effect is negative, and the types of research are effective substitutes for each other. This hypothesis can be tested on both public and private R&D. The agriculture sector is examined in Table 6 below.

Table 4 shows the main regression coefficients across the whole sample of the data.

Table 4: Determinants of Total Factor Productivity 1962-98

Explanatory Variables	Agr	Fish	For	Proc	Man	En	B/C	Trans	Ser	Mar
Stocks of R&D										
Private	2.91	0.07	-0.62	0.69	0.74	0.34	0.29	0.12	-0.33	0.39
	(6.7)	(0.1)	(-2.6)	(2.2)	(1.9)	(1.3)	(1.9)	(0.8)	(-2.3)	(3.1)
Public	-2.51	0.33	0.37	-0.18	-1.03	0.04	-0.16	-0.19	0.17	-0.38
	(-6.7)	(0.4)	(2.3)	(-0.6)	(-2.9)	(0.4)	(-1.1)	(-2.3)	(1.3)	(-3.3)
External	-0.46	0.57	1.39	0.35	0.42	0.26	-0.37	0.79	0.13	0.13
	(-2.7)	(1.0)	(5.7)	(0.2)	(5.2)	(3.6)	(-1.7)	(15.1)	(3.2)	(3.7)
Additional Variables										
Education	0.60	-1.13	-0.51	-0.29	0.16	-0.16	0.22	-0.22	-0.04	0.02
	(3.7)	(-2.8)	(-2.1)	(-1.8)	(1.0)	(-1.1)	(1.2)	(-2.5)	(-0.9)	(0.4)
Summary Statistics										
R^2	*0.96*	*0.78*	*0.91*	*0.94*	*0.63*	*0.98*	*0.59*	*0.97*	*0.92*	*0.95*
DW	*1.80*	*0.67*	*0.66*	*1.19*	*0.95*	*1.18*	*0.94*	*1.45*	*1.32*	*0.84*

(figures in parenthesis are t-values)

This analysis indicates that:

> Private R&D is positively related to changes in TFP in 7 cases out of 10;
> Public R&D is positively related to changes in TFP in 4 cases out of 10;
> External R&D is positively related to changes in TFP in 7 cases out of 10; and
> Education expenditure is positively related to changes in TFP in 4 cases out of 10.

The R^2 statistic is very high in 7 cases out of 10, with three equations indicating other explanatory variables should be sought. The DW statistic is satisfactory in 5 cases out of 10 indicating serial correlation is a problem among the independent variables and other transformations of the data should be examined.

The implications of the results for overall rates of return on R&D capital are shown in Table 5. In this table the regression coefficients are converted to overall rates of return by means of equation (5).

Thus the rate of return to private R&D is surprisingly high in Agriculture and Building and quite promising over the market sector as a whole. For Forestry and Services the results are perverse. The return on public R&D is low or negative throughout, rather confirming the Treasury view over the years that there has been over-investment or under-utilisation in public R&D. Negative returns show that in some sectors TFP has moved against the designated R&D stock on a consistent basis. Further investigation of rates of return changes some of these results (see appendix note).

Table 5: Rates of Return

($ return per $ of depreciated stock @ 5% at beginning of year)

Category	Agr	Fish	For	Proc	Man	En	B/C	Trans	Serv	Mark
Private R&D	68.7	1.6	-14.9	7.6	11.5	10.2	31.8	13.4	-4.6	11.9
Public R&D	-6.7	0.3	1.0	-3.7	-21.7	0.5	-11.8	-14.4	1.0	-4.8

The response (in Table 4) to Australian investment in R&D suggests that improvements in production may well free-ride on other R&D than that generated in NZ. Only Agriculture and Building move against this trend. The positive response to education in Agriculture, Manufacturing, and Building, is suggestive of industries with a need for higher skills. The coefficients are not highly significant.

Spillovers in Agriculture

In this section possible spillovers between private R&D stocks in a sector and other non-industry private R&D stocks, and between public R&D stocks and other non-industry public R&D stocks, are examined. Also the serial correlation problem existing between private and public stocks of R&D is examined by amalgamating the two variables. The results are set out in Table 6.

In the first half of Table 6, the results indicate amalgamated private and public R&D in agriculture gives inconclusive results; external R&D is dominant; serial correlation is present in all equations; non-industry R&D in the rest of the economy is significant; and other non-industry R&D tends to be a complement to agricultural R&D.

In the second half of Table 6, the strong return to private R&D in agriculture is re-confirmed; the return to public R&D is generally negative again; serial correlation is absent; private R&D in the rest of the economy is nearly significant but public R&D in the rest of the economy is not; non-industry private R&D in the rest of the economy is a substitute for private own-industry R&D (but not at a significant level); public R&D in the rest of the economy is not significant on its own but acts as a substitute at a significant level when combined with public own-industry R&D designated to agriculture.

The return on private R&D investment in agriculture varies between $30 and $85 per $ of depreciated research stocks (as compared with $68.7 in Table 5).

Table 6: Sensitivity Analysis for Agriculture

Variable	(1)	(2)	(3)	(4)	(5)	(6)
a.AmalgR&D	0.39	0.25	0.06	-0.02	-4.78	-4.97
	(10.4)	(0.4)	(0.5)	(-0.2)	(-6.3)	(-6.8)
b.External		0.62		0.61		
		(7.2)		(5.9)		
c.Education			0.72	0.06		
			(2.8)	(0.3)		
d.AmalgNonR&D					5.45	3.81
					(6.8)	(3.5)
e. ln a * ln d						0.13
						(2.1)
R^2	0.76	0.90	0.80	0.90	0.90	0.91
DW	0.31	0.76	0.43	0.76	0.90	1.05
f. Pvt R&D	1.24	1.91	2.28	2.91	3.02	
	(2.7)	(8.5)	(3.0)	(6.9)	(11.2)	
g. Pub R&D	-1.95	-1.91	-2.26	-0.09		
	(-7.0)	(-2.9)	(-7.2)	(0.1)		
h.. Non-Pvt-R&D	1.14		1.05			
	(1.7)		(1.8)			
i. ln f * ln h			-0.07			
			(-1.3)			
j. Non-Pub-R&D		0.41		-1.01		
		(0.5)		(-1.3)		
k. ln g * ln j				-0.13	-0.21	
				(-2.3)	(-9.7)	
R^2	0.94	0.94	0.96	0.95	0.95	
DW	1 .36	1.15	1.68	1.62	1.29	

Discussion

As far as the data is concerned, the aggregate estimates of R&D expenditure back to 1962 are fairly robust and the division between private and public R&D is very good. The disaggregation of total private and public R&D expenditure into the respective sectors is not at the same level of accuracy and reflects a set of approximations, especially in the allocation of private R&D. The public R&D disaggregation is based on quite good historical data. Public and private stocks are dependent on the depreciation assumption, and results so far indicate a lack of sensitivity to the rates used. The actual stocks of public and private R&D tend to be highly correlated, though amalgamating them in the agricultural analysis does not produce better results**.**

Private R&D tends to show higher and more positive returns than public R&D across all sectors. Some quite high returns to R&D are apparent. There are unexplained associations with external sources of R&D (as represented by the Australian stocks of private R&D) that suggest public good characteristics in the knowledge industry and considerable transfer of ideas in the user community. In some sectors, the level of real education expenditure indicates a skilling attribute in the labour force, but is relatively unimportant.

In the agriculture sector, amalgamated R&D (private+public) does not appear to work in a statistical sense. External R&D seems to be the main causative factor when this variable is used. There is a suggestion that non-agricultural research stocks have positive effects on agricultural TFP which is consistent with wide transfers of ideas between sectors. There is a small complementarity between designated total R&D in agriculture and non-designated total R&D in the rest of the economy.

However, using private non-industry R&D and public non-industry R&D as variables appears to stabilise the estimation equations from a serial correlation point of view. The positive effect appears to come from private R&D rather than public R&D. There are clear indications in this last set of estimations that both private and public non-industry R&D act as substitutes for own-industry R&D. This result tends to confirm the public pool concept of R&D rather than seeing it as a private good which is appropriable.

Having established this data base of R&D in New Zealand for the years since 1962, more research could profitably be undertaken on the lagged responses of productivity to research investment in each sector as well as improving the statistical properties of the regression results. There may also be refinements of the data set that could be accomplished with further investigation of data sources (see appendix note).

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Technical Appendix: The Rate of Return to New Zealand Research and Development Investment

These notes report aspects explored but not included in the text of the paper. As explained in the paper, not all sectors in SNA were matched by R&D data.

DEFINITION OF CAPITAL ASSETS IN TOTAL FACTOR PRODUCTIVITY (TFP)

Philpott (1995) provides definitions of capital assets on a net and a gross basis. The net basis is derived from standardised depreciation rates; the gross basis is derived from a vintage model of capital where individual assets are phased out after an estimated lifetime. Generally speaking, the net series is two thirds of the gross series in constant prices. We tested for the Market Economy (MK) and Manufacturing (MN) sectors whether the mean of the two estimates of capital influenced the result in Table 4. Taking the means lowers the capital estimates and raises the TFP estimates. In MN the estimated elasticities are slightly lower. The rates of return will consequently be slightly higher.

Market economy:

Equation	PV	PU	AU	EDU	DW
	b t	***b t***	***b t***	***b t***	
Previous	0.40 (3.1)	-0.39 (-33)	0.13 (3.7)	0.02 (0.4)	.84
Estimated	0.38 (2.)	-0.36 (-3.0)	0.14 (3.9)	0.01 (0.2)	.88

Manufacturing sector:

Previous	0.75 (1.9)	-1.03 (-2.9)	0.43 (5.2)	0.16 (1.0)	.95
Reestimated	0.66 (1.)	-0.96 (-2.7)	0.44 (5.1)	0.18 (1.1)	.92

(PV = private R&D; PU = public R&D; AU = Australian private R&D; EDU = public education expenditure; *DW* = Durbin-Watson test; *b* = regression coefficient; *t* = "t" test)

FIRST LOOK AT RATES OF DEPRECIATION

All capital stocks for R&D in Table 4 were depreciated at 5% per year. Ten per cent depreciation was tested for the market economy and manufacturing sectors with no significant differences emerging.

Market economy:

Equation	PV	PU	AU	EDU	DW
Previous	0.40 (3.1)	-0.39 (-3.3)	0.13 (3.7)	0.02 (0.4)	.84
Reestimated	0.39 (3.0)	-0.38 (-3.2)	0.14 (3.8)	0.01 (0.2)	.85

Manufacturing sector:

Previous	0.75 (1.9)	-1.03 (-2.9)	0.43 (5.2)	0.16 (1.0)	.95
Reestimated	0.71 (1.8)	-0.99 (-2.8)	0.44 (5.2)	0.14 (0.8)	.91

DROPPING NON-SIGNIFICANT VARIABLES

Equation	PV	PU	AU	EDU	DW
Fishing					
Previous	0.07 (0.1)	0.34 (0.5)	0.57 (1.0)	-1.13 (-2.8)	.67
Reestimated	-0.61 (-2.6)	1.13 (5.7)		-0.90 (-3.4)	.66
Energy:					
Previous	0.34 (1.3)	0.04 (0.4)	0.26 (3.6)	-0.16 (-1.1)	1.18
Reestimated	0.19 (13.3)	0.34 (11.9)			1.23
Building:					
Previous	0.29 (1.9)	-0.16 (-1.1)	-0.37 (-1.6)	0.23 (1.2)	.94
Reestimated	0.13 (2.6)		-0.13 (-2.2)	0.05 (0.6)	.91
Transport:					
Previous	0.12 (0.9)	-0.19 (-2.3)	0.79 (15.2)	-0.22 (-2.5)	1.45
Reestimated		-0.16 (-9.6)	0.74 (24.4)		1.15
Services:					
Previous	-0.33 (-2.3)	0.17 (1.3)	0.13 (3.3)	-0.04 (-0.9)	1.33
Reestimated	-0.15 (-7.0)		0.08 (3.6)	-0.02 (-0.4)	1.24

These results did not indicate any particular pattern to follow. The results in Table 4 should be judged as a whole.

DISTRIBUTED LAGS IN THE R&D STOCKS

This is a question of whether to use annual data for R&D as the independent variables or to construct "stock" variables using pre-determined depreciation rates. The paper is based on the latter approach. To more systematically understand which approach to take, stocks were estimated for 5%, 10%, 20%, 30%, 40% and 50% depreciation rates for the MK and AG data sets and the regressions re-run. Secondly, polynomial distributed lags (PDLs) were estimated for the same data using the Almon formula. For the depreciation model we are using the specification:

$$TFP_t = f(PV_{t-1}, PU_{t-1}, AUR_{t-1}, EDU_{t-1})$$

The Almon PDLs are based on the following specification:

$$TFP_t = f(PVE_{t-1}, PVE_{t-2}, \ldots\ldots PVE_{t-15}) \quad (E = \text{annual expenditure})$$

(i) Depreciation rates:

This equation includes Australian R&D and educational expenditure and has the best DW.

Rate	MKPV		MKPU		AGPV		AGPU	
	b	$ror	*b*	$ror	*b*	$ror	*b*	$ror
5%	.34	10.2	-.35	-4.4	2.59	61	-2.32	- 6.2
10%	.30	13.2	-.29	-5.3	2.28	86	-1.98	-7.8
20%	.20	14.6	-.20	-6.2	1.61	100	-1.46	-9.6
30%	.15	15.6	-.17	-7.5	1.28	111	-1.24	-11.6
40%	.12	16.1	-.15	-8.5	1.08	120	-1.11	-13.5
50%	.11	18.2	-.14	-9.8	0.95	128	-1.03	-15.3
Annual	.07	22.4	-.07	-9.5	0.69	178	-0.65	-18.7

($ror = rate of return per $ of depreciated investment in R&D)

As was shown in Table 4, total factor productivity was positively related to private R&D stocks and negatively related to public R&D stocks in the Market Economy (MK) and Agriculture (AG) sectors. But as is demonstrated above, manipulation of the depreciation rate is compensatory (at least for the two sectors shown). The elasticity decreases as the depreciation rate rises until annual data takes over completely (remember that 50% depreciation implies that most of the change in TFP is "explained by" the previous years' investment in R&D and only half the stock of a year earlier and so on).

The rate of return on the investment in R&D (as defined) is remarkedly constant across different depreciation rates. Immediate past investment dominates all the results**.** The general pattern remains one of positive returns for private R&D and negative returns for public R&D in the specification employed.

(ii) Polynomial distributed lags:

PDLs provide smoothed coefficients determined by fitting a polynomial function to past annual values of a predetermined number of years of the independent variable. In this case the number was set at the 16th year. The current value of the independent variable is dropped. Other possible influential variables are not included so all possible gains are attributed to the one independent variable. Private and public R&D equations are estimated separately for each sector.

Lag	**MKPVE**		**MKPUE**		**AGPVE**		**AGPUE**	
	b	**$ror**	***b***	**$ror**	***b***	**$ror**	***b***	**$ror**
-1	-.001	-0.1	.130	1.2	.147	2.5	.459	0.9
-2	-.026	-0.6	.045	0.4	.114	2.0	.207	0.4
-3	-.040	-0.9	-.014	-0.1	.088	1.5	.029	0.1
-4	-.044	-1.0	-.051	-0.5	.070	1.2	-.085	-0.2
-5	-.040	-0.9	-.068	-0.6	.058	1.0	-.145	-0.3
-6	-.030	-0.7	-.070	-0.6	.052	0.9	-.160	-0.3
-7	-.016	-0.3	-.059	-0.5	.049	0.8	-.140	-0.3
-8	.001	0.1	-.040	-0.4	.049	0.8	-.094	-0.2
-9	.018	0.4	-.016	-0.1	.050	0.9	-.034	-0.1
-10	.035	0.8	.010	0.1	.052	0.9	.032	0.1
-11	.048	1.1	.034	0.3	.053	0.9	.094	0.2
-12	.056	1.2	.052	0.5	.051	0.9	.143	0.3
-13	.057	1.2	.061	0.5	.046	0.8	.167	0.3
-14	.049	1.1	.058	0.5	.037	0.6	.158	0.3
-15	.031	0.7	.039	0.4	.022	0 4	.105	0.3
Sums	.096	2.1	0.112	1.1	0.940	16.1	.736	1.4
Turning points		4, 13	6, 13		6, 12	6, 13		

As these regressions are multifactorial, each coefficient is an estimate of the elasticity with regard to that time lag. The sum of the coefficients gives the average elasticity with respect to R&D. In all cases, the sum is positive and looks as though it will stay positive though diminishing quickly as extra years are included. Contrary to previous results, therefore, the return to R&D expenditure is now positive if the longer term is taken into account. There is also a distinct short term benefit apparent in three cases. *Thus the pattern of build-up and use of a stock of knowledge may not follow any particular perpetual inventory rules*. These results show that in each case the return function is not monotonic, and hence two turning points appear. In this case, the mean lag estimation cannot be relied upon.

Negative returns can be interpreted as delays in the production process following new expenditure on R&D. On average, the delays appear to be of the order of 4-6 years before production responds, and the peak response is reached after 11-13 years. This compares with Scobie and Eveleen's estimate of 11 years for the agriculture sector for the period 1920-1980. These results therefore need further investigation across all sectors before conclusive conclusions can be obtained.

The following table shows the sum of the elasticity coefficients for annual expenditures on R&D in eight sectors and the total market economy examined in this project (the services sector has no separate identifiable R&D):

Sector	**Private R&D** **sum**	 **$ror**	**Public R&D** **sum**	 **$ror**
Agriculture	.940	16.2	.736	1.41
Fishing	.939	14.2	.506	0.32
Forestry	.821	15.1	-.632	-1.14
Processing	.408	3.14	.256	3.71
Manufacturing	.195	2.02	-.201	-3.00
Energy	.355	7.26	.197	1.75
Building	.837	62.5	.258	10.2
Transport	.339	25.2	-.187	-8.98
Market economy	.096	2.05	.112	1.01

In most cases a positive return is now obtained. The exceptions are public R&D in the forestry, manufacturing and transport sectors. The magnitude of the rate of return estimate has to be interpreted as a social dividend to previous research undertaken by private and public agencies. It is not an internal rate of return which would have to take account of the lags in the response times. Scobie quotes an internal rate of return for agriculture of 30 per cent. These results suggest higher internal rates of return than this. The sectors with negative returns are characterised by long waits for positive results to be apparent.

These results also confirm that the turning points are fairly uniform across sectors at 4-6 years in the medium term and 12-13 years in the longer term. Since these results are so uniform it is likely that there is a common driving force behind the equations - this appears to be the link of R&D expenditure to GDP. On the other hand, the elasticities are also determined by changes in sectoral GDP which in some sectors is very different from the aggregate. This will be investigated further.

THE COBB-DOUGLAS SPECIFICATION: ARE FACTOR SHARES APPROXIMATED?

(equation (3) in the paper)

(i) Estimates of coefficients of Cobb-Douglas production function without R&D 1962-98:

Sector	**LFS**	**"*a*"**	**"*b*"**	**R^2**	**DW**
AG	.63	-2.55 (-6.1)	2.41 (8.7)	.84	.76
FS	.48	0.64 (1.6)	0.75 (5.1)	.91	.26
FO	.15	-0.46 (-2.3)	2.94 (10.0)	.81	.28
PC	.66	0.54 (4.7)	0.94 (29.1)	.96	.80
MN	.53	0.43 (3.8)	0.27 (10.1)	.79	.55
EN	.28	0.06 (1.1)	1.69 (66.0)	.99	.64
BD	.72	0.75 (7.5)	0.57 (7.0)	.81	.64
TR	.71	-0.71 (-2.4)	0.46 (6.4)	.67	.20
SV	.61	0.51 (5.2)	0.25 (6.1)	.99	.68
MK	.60	0.54 (5.2)	0.56 (18.9)	.98	.32

As equation (3) in the paper shows, the returns on R&D stocks can be estimated with GDP as the dependent variable and "labour" and "capital" as independent variables. This provides a check on the summing properties of the *a* and *b* coefficients, and also the effect on the rate of return to R&D. All DW statistics are very low hence serial correlation is present throughout. Average factor shares (LFS=labour share) are 60:40, but sectors differ. Only MK provides some approximation to the average, with SV and MN somewhere near. The EN, FO and AG sectors are obviously capital responsive, as is processing. AG, FO and TR are declining employment sectors, especially in later years. The influence of additional variables is discussed below.

(ii) Adding the R&D and "other" variables to the Cobb-Douglas specification 1962-98 (as in equations in (i) above):

	"*a*"		**"*b*"**		**PV**		**PU**		**AU**		**EDU**		**DW**
AG	-2.56	(-6.1)	2.42	(8.7)									.76
	0.66	(1.3)	1.63	(2.2)	2.24	(6.3)	-2.01	(-5.7)					1.23
	1.08	(2.5)	2.15	(1.6)	2.56	(3.9)	-2.57	(-5.6)	-0.1	(-0.2)	0.5	(2.8)	1.87
FS	0.64	(1.6)	0.80	(5.2)									.26
	0.74	(1.8)	-1.10	(-2.2)	0.10	(0.2)	1.24	(5.2)					.74
	0.17	(0.4)	-1.06	(-2.4)	1.08	(.06)	0.61	(0.9)	0.5	(1.0)	-1.1	(-2.9)	1.00
FO	-0.46	(-2.3)	2.94	(10.0)									.28
	-0.07	(-0.7)	-0.28	(-0.7)	0.57	(6.8)	0.06	(0.5)					.62
	-0.38	(-0.1)	0.38	(0.7)	-0.25	(-1.0)	0.37	(3.1)	0.94	(4.1)	-0.51	(-2.7)	.98
PC	0.54	(4.7)	0.95	(29.1)									.80
	-0.12	(-0.5)	-0.37	(-0.7)	-0.51	(-1.3)	1.29	(3.5)					1.25
	-0.04	(-0.2)	-0.34	(-0.4)	-0.15	(-0.3)	1.00	(2.4)	-0.1	(-0.7)	-0.1	(-0.1)	1.33
MN	0.43	(3.8)	0.27	(10.1)									.55
	0.51	(3.2)	0.42	(1.3)	0.12	(0.2)	-0.23	(-0.41)					.55
	0.75	(4.7)	-0.20	(-0.5)	1.38	(1.7)	-1.19	(-2.1)	0.44	(2.6)	0.07	(0.3)	.99
EN	0.06	(1.1)	1.69	(66.0)									.64
	0.17	(2.6)	0.63	(2.6)	0.45	(2.8)	0.02	(0.4)					.97
	0.20	(2.6)	0.73	(2.7)	0.45	(1.5)	0.01	(0.01)	0.04	(0.4)	-0.10	(-0.8)	.96
BD	0.75	(7.5)	0.57	(7.0)									.64
	0.94	(9.8)	0.21	(1.1)	0.06	(2.1)	0.05	(0.6)					.88
	0.99	(11.2)	0.55	(2.4)	0.58	(3.4)	-0.47	(-2.6)	-0.59	(-2.7)	0.16	(0.9)	1.23
TR	-0.71	(-2.4)	0.46	(6.4)									.20
	0.02	(0.1)	-1.54	(-3.8)	1.06	(2.3)	0.09	(0.2)					.37
	0.52	(3.0)	-0.32	(-1.7)	-0.07	(-0.4)	0.16	(1.2)	0.71	(12.5)	-0.16	(-1.4)	1.71
SV	0.51	(5.2)	0.25	(6.1)									.68
	0.81	(8.5)	0.38	(8.2)	-0.35	(-2.5)	0.16	(1.4)					1.32
	0.75	(6.1)	0.33	(3.3)	-0.37	(-2.5)	0.21	(1.5)	0.06	(0.6)	-0.02	(-0.2)	1.31
MK	0.54	(5.2)	0.56	(18.9)									.32
	1.06	(12.5)	0.58	(4.1)	0.70	(4.5)	-0.78	(-7.1)					.89
	0.95	(9.3)	0.37	(1.7)	0.57	(3.5)	-0.59	(-3.6)	0.07	(1.2)	0.03	(0.5)	.96

While the introduction of more variables has stabilised the DW ratio, only EN and SV have labour and capital coefficients that resemble the factor shares. Marginal products are by implication either too high or too low. Euler's theorem is not observed. In the case of returns to R&D; for private R&D seven sectors give similar results to those in Table 4 of the paper, but three are quite changed (FS, PC, & TR); for public R&D eight sectors are similar, but two are not (PC, TR). Thus in two sectors, the Cobb Douglas specification gives quite different results for the elasticity with respect to R&D.

(iii) Cobb Douglas coefficients by sub-periods: (3rd specification in (ii) above):

Period	1962-83		1984-98		1962-98	
Variable	*a*	*b*	*a*	*b*	*a*	*b*
AG	.79	3.28	.76	5.97	1.08	2.14
FS	.70	-.94	.09	-.35	.17	-1.06
FO	-.60	-3.46	.46	-7.2	-.04	.37
PC	.32	.67	.33	-1.33	-.04	-.34
MN	.59	-1.15	.38	.32	.75	-.20
EN	.13	-.78	.07	-.52	.20	.73
BD	1.11	.42	1.05	.85	.99	.55
TR	-.38	.22	.46	.57	.52	-.32
SV	-.09	2.67	.24	-.37	.76	.33
MK	1.81	-1.35	.69	-.75	.95	.37

In the sub periods the coefficients do not follow factor shares in any systematic way. Trends in labour and capital inputs in these periods are not entirely random but appear to be influenced by the build-up of investment or labour force changes unrelated to annual output.

(iv) R&D coefficients by sub periods: (3rd specification in (ii) above):

Period	1962-83		1984-98	1962-98		
Variable	PV	PU	PV	PU	PV	PU
AG	2.40	-2.47	1.10	-.41	2.56	-2.57
FS	-1.38	2.78	2.15	.45	1.18	.61
FO	1.36	1.42	1.96	-1.34	-.25	.37
PC	-1.19	1.77	1.37	.47	-.15	.99
MN	.62	-.34	-.27	1.41	1.38	-1.19
EN	1.51	-.16	-.02	.09	.46	.98
BD	.69	-.96	-.25	.52	.58	-.47
TR	-1.05	.27	-.19	-.45	.-.07	.16
SV	1.77	-3.50	-.99	1.89	-.37	.21
MK	.96	-.04	.04	1.07	.57	-.59

In some cases, the whole period appears to be the average of the sub periods but in others random factors appear to be pulling the results apart, e.g. MN, EN, SVand MK. In turn, these variable results lead to variable estimates of the rate of return on R&D capital (5% depreciated).

(vi) Rate of return on R&D stocks of capital ($return per depreciated $ invested) (coefficients from (iv) above):

Period	1962-83		1984-98	1962-98		
Variable	PV	PU	PV	PU	PV	PU
AG	58	-8	24	-1	60	-7
FS	-25	3	45	0.4	27	0.5
FO	65	4	57	-3	-6	1
PC	-17	44	11	7	-2	21
MN	12	-11	-3	21	21	-25
EN	48	-2	-1	1	14	13
BD	134	-41	-17	17	63	-34
TR	-122	16	-14	-14	-9	11
SV	33	-26	-10	8	-5	1
MK	39	-1	1	10	17	-7

These results need to be interpreted in context. If there is a coincidence of GDP change and R&D stock available, the log-log coefficient (elasticity) can be quite responsive. Hence, in some cases (PV in BD and AG) very high returns to previous investment in R&D show up. On the other hand, negative coefficients, reflecting inverse annual changes between GDP and R&D stocks available, are reasonably frequent across all sectors. Since these are over considerable periods of time in each sub period, it can only be concluded that output is not driven by any notions of *recent* scientific activity in these sectors. Explanations could be sought in the Almon PDLs for example.

THE INCENTIVE TO INVEST IN R&D

Current levels of annual spending in R&D could be explained by expected returns from such investment. If expected returns can be hypothesised as some function of previous income like a distributed lag system, then a relationship like the following could be investigated:

$$R\&DExp_{t,i} = f(TFP_{t,i}, TFP_{t-1,i}, \ldots\ldots TFP_{t-14,i})$$

The following table shows the results (again) for the market and agriculture sectors. Estimated coefficients for:

Lagged Income	**MKR&DPV**	**MKR&DPU**	**AGR&DPV**	**AGR&DPU**
0	.60	-.41	.28	-.01
-1	.17	-.23	.10	-.03
-2	-.10	-.06	-.02	-.04
-3	-.24	.08	-.08	-.03
-4	-.27	.20	-.09	-.02
-5	-.22	.30	-.06	.01
-6	-.11	.37	-.01	.04
-7	.05	.43	.06	.07
-8	.22	.46	.13	.09
-9	.39	.46	.21	.12
-10	.53	.44	.27	.13
-11	.62	.40	.30	.14
-12	.63	.34	.30	.13
-13	.55	.25	.26	.11
-14	.35	.14	.16	.06
Sums	3.17	3.17	1.81	0.76
Turning points	4, 12	0, 9	4, 12	2, 11

The coefficients from log-log relationships are estimates of the elasticities of response to increases in sectoral national income or propensities to invest. Thus we interpret the results for the market economy as a 0.6% (in the first year) and a 3.2% change (overall) in R&D investment per 1% change in sectoral GDP. The sums for all sectors are as follows:

	Sector	**Private R&D**	**Public R&D**
	AG	1.8	0.8
	FH	-0.3	1.6
	FO	2.9	0.1
	PC	0.4	-0.6
	MN	-1.2	-1.0
	EN	-0.1	-0.7
	BD	5.1	-
23.9			
	TR	-0.8	-0.7
	MK	3.2	3.2

There is a long run response for private R&D to changes in own GDP in agriculture, forestry, processing, and building. The long run response is positive for public R&D in agriculture, fishing and forestry. Negative propensities to invest indicate that R&D in these sectors is not driven by past income over a 14 year time period.

Glossary of Terms

AG	Agriculture sector (farming only)
BD	Building and Construction sector
BERL	Business and Economic Research Limited
DW	Durbin-Watson test for serial correlation
EN	Energy, Gas and Water sectors
Factor income	The return to labour and capital in national income
FS	Fishing sector (but not processing)
FO	Forestry sector (but not processing)
GDP	Gross Domestic Product
MAF	Ministry of Agriculture and Forestry
MK	Market Economy (excluding dwellings and Government services)
MN sectors	Mining, Basic metals, Chemicals, Non-metallics, Machinery
MoRST	Ministry of Research, Science and Technology
NZIER	New Zealand Institute of Economic Research
PC	Primary Processing sector
R^2	A measure of goodness of fit of a regression equation
R&D	Research and Development (expenditure)
SNA	System of National Accounts (of the United Nations)
STAC	Science and Technology Advisory Committee
SV sectors	Trade, Communications, Finance and Community Services
TFP	Total Factor Productivity
TR	Transport sector