

MINISTRY OF  
RESEARCH  
SCIENCE +  
TECHNOLOGY

**M<sup>+</sup>RST**  
TE MANATŌ PŪTAIAO

# **The development of a time series of Business Enterprise R&D Statistics**

Methodology of  
*Research and Development in New Zealand  
– A Decade in Review.*

## Summary

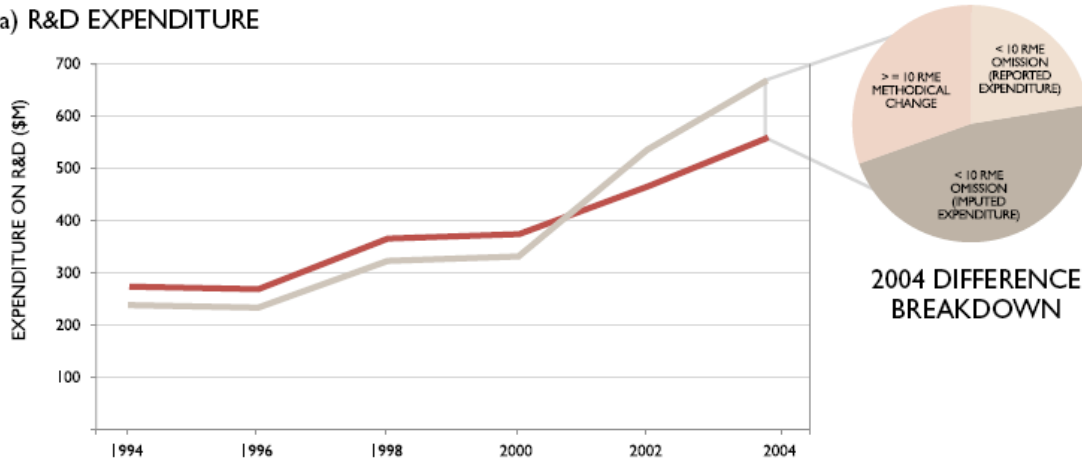
The time series of business expenditure on R&D included in the MoRST (2006) publication *Research and Development in New Zealand – A Decade in Review* has been revised from the data previously published by Statistics New Zealand and MoRST. This was necessary to ensure that the series is as consistent as possible over time. The key points in the strategy are as follows:

- The estimates for most firms with less than 10 employees have been excluded from the results from each of the years of the series. This is because the data is essentially unstable, suffering from high sampling errors (in 2004) and potentially larger non-sampling errors (in all years). The exception to this rule is in respect of the Scientific Research industry which has been fully enumerated and therefore will have no sampling errors and will have smaller non-sampling errors than other businesses as they are more likely to keep records about R&D leading to better data reporting.
- The change in survey population identified in the 2002 survey has been used to develop a set of adjustment factors for 2000 and earlier years to bring those years into line with the 2002 base. Factors have been developed and applied for broad industry by size groups.
- The level of R&D measured in the 2004 survey has been reduced by an amount to reflect the break in comparability introduced from the changed methodology in 2004. This comparability break has been approximated by estimating the effects of the sampling approach and the other methodological changes and reducing the level of the published 2004 estimate by this amount. This adjustment has been made for the firms in the 10–50 employee range group. This strategy essentially means that the 2004 survey results have been benchmarked to the 2002 survey.
- No adjustment has been made to the 2004 survey for the group of firms with 50+ employees, on the grounds that the sampling effects in this group are minimal. There may be some underestimation of the methodological change impacts because no allowance has been made for the impact of other methodological changes in this group (mainly the finding of new R&D performers). However, there is no adequate method to estimate this impact and any impact is expected to be small.
- Firms have been classified to industry strictly on the basis of the Australia–New Zealand Standard Industry Classification (ANZSIC) allocated by Statistics New Zealand. This aligns with the guidelines in the *Frascati Manual*. The net effect of this change has been to re-allocate some R&D previously included in the Primary, Manufacturing and Services sectors to the Scientific Research industry.

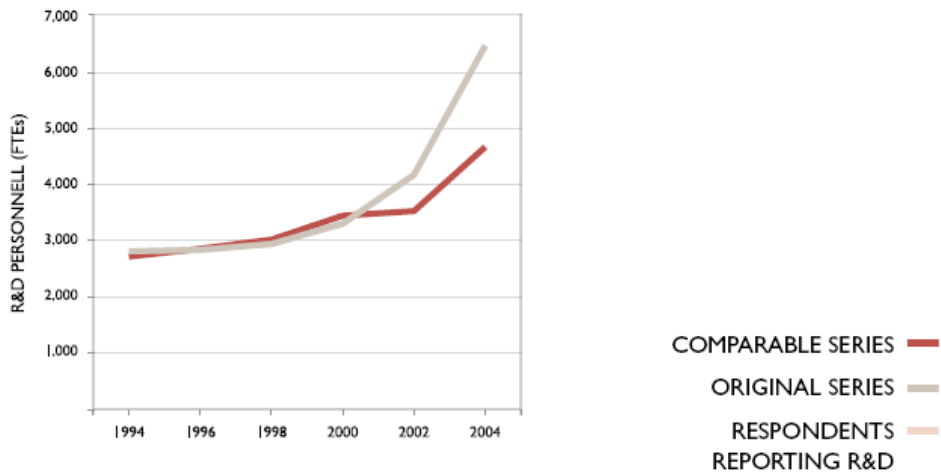
The revised series, compared to the latest published statistics, is shown graphically overleaf. The reasons for the changes to the published series for 2004 have been marked on the graph.

CHART 1. COMPARISON OF REVISED COMPARABLE SERIES AND ORIGINAL PUBLISHED SERIES

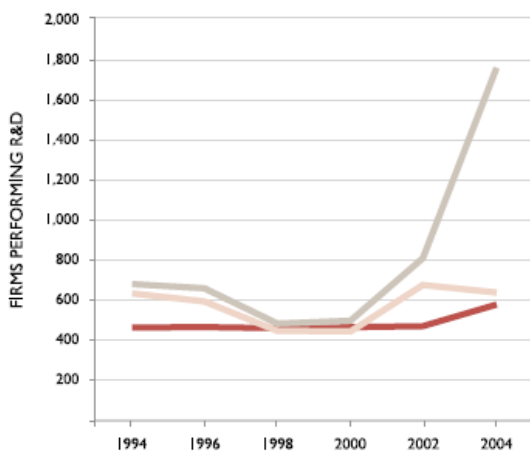
a) R&D EXPENDITURE



b) R&D PERSONNEL



c) NUMBER OF FIRMS



## INTRODUCTION

This paper outlines the results of the work undertaken in MoRST to prepare a consistent time series of business enterprise R&D data for the publication *Research and Development in New Zealand - A Decade in Review*. Without a consistent time series it is not possible to plot the path of New Zealand R&D, to measure the actual rate of change in the level of R&D and the distribution of that R&D by sector, industry and size.

This paper concentrates most attention on the measurement of a time series of R&D expenditure. However, similar methodologies have been adopted for the other main variable emanating from R&D surveys – namely the human resource input into that R&D.

## METHODOLOGIES OVER TIME

### 1994–2000

From 1994 – 2000 the methodology adopted was to undertake a census of known R&D performers. The population for the surveys derived from lists provided by MoRST and its funding agencies, supplemented by enterprises that had previously reported R&D. If the size of the population became too large, the survey population was modified using industry knowledge.

In 1998, it appears that the list did in fact become too large. Thus a methodology was adopted which essentially led to the exclusion of a number of firms with small amounts of R&D, generally a subset of those that reported less than \$50k in the previous (1996) survey. The same procedure appears to have been implemented in 2000. As the enterprises omitted were mainly those with <\$50k R&D expenditure, the impact on the total value of R&D expenditure was fairly minimal, although estimates of the actual number of enterprises performing R&D have been more significantly affected.

The methodology adopted to overcome this methodological change was to estimate the share of number of enterprises that had been excluded from the 1998 survey, and to use this factor to reduce the published estimates for 1994 and 1996. This had the effect of bringing each year of the series from 1994 to 2000 onto the same basis – thus ensuring that the same set of re-benchmarking factors could be applied consistently to overcome the methodological change introduced in 2002 described below.

The impact of this adjustment to the value of R&D expenditure for 1994 and 1996 was only minimal – approx \$3m, or about 1% of the total estimate.

## 2002

The 2002 survey saw the first of two major comparability breaks occurring in the survey methodology. The changes in 2002 related to the adoption of a new source of information about specific businesses performing R&D. This information came from the 2001 Business Practices Survey. That survey revealed that 4,142 private businesses said they did R&D. After a follow up study, it was estimated that the true number of firms undertaking R&D was more likely to be 1,706. This was significantly greater than the 2000 list.

As part of the release of results from the 2002 survey, Statistics New Zealand developed, and published at the very broad level, a set of statistical aggregates that would have been obtained had the 2000 list procedure been adopted for the 2002 survey. This provides the linking mechanism for the survey results for 2002 with those for earlier periods.

In the 2002 Statistics New Zealand and MoRST R&D publication, the data for key aggregates for 2002 were reported in two ways, using the new criteria and using the old (2000) criteria. In the 2004 publication no revisions to results from 2002 or previous years were made, mainly because the break in series in 2004 could not be quantified.

For this analysis, MoRST has used the information contained in the unit record file for the 2002 survey (supplied by Statistics New Zealand) to re-benchmark the 2000 and earlier years data. This has been done by identifying the additional units added to the survey as part of the methodological change – thus providing MoRST with the ability to derive coverage ratios that enables it to approximate the series for earlier years. In this way, statistics for each of the years from 1994 to 2000 were re-benchmarked to the 2002 level.

## 2004

The changes in 2004 relate to the introduction of a random sampling procedure based on the Statistics New Zealand Business Frame supplemented by a list of significant firms known to undertake R&D. This methodology was introduced to take into account the under-coverage from earlier years. The intention was to survey all businesses that were performing R&D according to the AFUS survey, which would have enabled a bridge to have been easily built between 2002 and 2004. However due to the 2004 AFUS results showing more than 2,800 firms indicating they carried out R&D, a full survey of those businesses became impractical. For this reason the sampling methodology adopted in the 2004 survey was expanded to sample these businesses. The increase in the number of R&D businesses in AFUS was due to a greater coverage of AFUS and an updated R&D question within the AFUS questionnaire (defining R&D based on *Frascati Manual* definitions and excluding market research, efficiency studies and style changes to existing products). This

confirmed that the 2002 population used for the survey was still likely to be missing a number of the businesses that had actually performed R&D.

The sampling methodology introduced in 2004 had the following design features:

- All known significant R&D firms, large firms with high turnover and firms in the ‘Scientific Research’ industry (L781) were fully enumerated.
- Medium size firms were sampled with high probabilities of selection, and
- Smaller firms had low probabilities of selection.

Unfortunately, due to the late results of the 2004 AFUS and the late change in methodology to incorporate these results, Statistics New Zealand has not been able to develop an official comparable bridge between the 2002 and 2004 R&D survey results. Six methods were tested by Statistics New Zealand in attempting to build a comparability bridge but none of the six provided adequate results.

For its Decade in Review publication, MoRST requires a time series of data that is consistent over time from 1994 to 2004 – so that it can effectively measure the changes that have occurred in the R&D system in New Zealand over this period. Because of this, MoRST has decided to develop its own link between the 2002 and 2004 surveys to try and complete the time series from earlier years. This paper summarises the methodologies adopted, conclusions drawn and the estimates of the impacts of the methodological changes confronted.

A further issue with the comparability of survey results over time has been a procedure introduced a few surveys ago in which a number of businesses have had their industry recoded at the completion of the survey. The reason for this change has been to try to convert the survey results to better reflect the industry benefiting from the R&D. This type of procedure has been adopted by a number of countries round the world.

The *Frascati Manual*<sup>1</sup>, on which R&D survey methodologies are based, recognises the value of having results classified in some way to measure the beneficiary industry. It recommends that such statistics ought to be compiled but recommends that this should happen through using a different methodology – by collecting additional information on the product field to which the R&D relates and compiling additional statistics about the product field to which the R&D is directed.

The *Frascati Manual* does not recommend that any changes be made to the industry classification. For this reason, R&D has been classified to industry for this publication strictly according to ANZSIC and no reclassifications have been adopted.

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<sup>1</sup> OECD, 2002. *Frascati Manual: Proposed standard practice for surveys on research and experimental development*.

This manual provides standard definitions relating to collection of R&D data through surveys, and is used throughout OECD member countries.

### FIRM SIZE GROUPS USED IN THIS REPORT

We have classified firms according to rolling mean employment (RME) measured in full time equivalents (FTEs) using the following groupings:

less than 2	2 or less FTEs
2-10	2 or more and less than 10 FTEs
10-50	10 or more and less than 50 FTEs
50+	50 or more FTEs

### THE EFFECT OF THE CHANGES IN 2002 AND 2004.

The effect of the changes in 2002 and 2004 has been to introduce a much larger number of respondents to the survey indicating that they have carried out R&D. This has particularly noticeable in the smaller size groups of firms but has also happened for medium and large businesses as well. The increase in number of firms reporting R&D and the value of that R&D has been spread across all the industries in the survey i.e. across each of the Primary, Manufacturing and the Services sectors of the economy.

In addition to the finding of respondents not previously considered to be R&D performers, the 2004 aggregates also now include an allowance for other (unknown) firms that were also conducting R&D. In past surveys no such allowance had been made. Between the 2000 and 2004 surveys, the level of R&D recorded in the published results has risen from \$324m to \$677m, more than doubling.

Table 1 below shows a summary of the aggregates (in total for all industries) included in the published results from 1994, and up to the most recent survey in 2004.

TABLE 1. REPORTED R&D EXPENDITURE OF SMALLER SIZED FIRMS

	Firms with <2 emps	Firms with 2 - 10 emps	Firms with 10 - 50 emps
1994	\$ 4 m	\$ 20 m	\$ 29 m
1996	\$ 5 m	\$ 18 m	\$ 52 m
1998	\$ 5 m	\$ 20 m	\$ 51 m
2000	\$ 6 m	\$ 22 m	\$ 55 m
2002	\$ 12 m	\$ 64 m	\$ 117 m
2004	\$ 27 m	\$ 74 m	\$ 195 m

As can be seen quite clearly, the levels being recorded in the period 1994 – 2000 appears to be quite consistent. However the changes that have occurred from the last two surveys place the series on a different level and without adjustment in some way would render useless the measurement of change over the length of the time series.

## THE REASONS FOR THIS RESULT

There are many reasons for the result shown above – most of which can be viewed as either the sampling or non-sampling errors inherent in the current survey strategy.

### SAMPLING ERRORS

Statistics New Zealand has provided some estimates of the sampling errors associated with the estimates of levels for the categories listed above (for all industries combined). The sampling errors provided are as follows:

Less than 2 employees – 30%  
2 – 10 employees - 45%  
10 – 50 employees – 9%.

What these sample errors tell us is that the estimates for the smaller size categories are quite unreliable, even at the total all industries level. Sampling errors for these size categories for specific industry sectors within the total will be even higher.

However, the position appears to be a little different for the 10 – 50 employee group, where the sample errors (9%) in total are sufficiently small and would appear to be quite acceptable for normal analysis. Of course, it is to be expected that the sample errors for the 10 – 50 employee group would be much smaller than for the smaller firm size groups as there is far less reliance on random sampling in the larger firm size group i.e. the probabilities of selection are greater.

### NON-SAMPLING ERRORS

Non-sampling errors can be a particular problem in R&D surveys and are most likely to be a large problem for the smaller businesses. Two particular forms of non-sampling error which are especially important in the case of smaller businesses arise as a result of:

- Difficulties in the identification of true *Frascati Manual* R&D in firms, particularly those in the Services sector of the economy, and



- Lack of record keeping practices about R&D in firms with no specialist R&D units meaning that a lot of the data reported is often a “best guess”.

It has generally been found round the world that most research activity performed in smaller businesses is more closely related to market research and the “tweaking” of existing ideas and technologies to improve a firm’s productivity or to increase their market penetration. The work can therefore be generally described as being innovative at the level of the firm (and as such might be suitable for inclusion in an Innovation Survey) but does not meet the strict definition of *Frascati Manual* R&D.

The latter is defined as:

*“creative work undertaken on a systematic basis to increase the stock of knowledge... and the use of this stock of knowledge to devise new applications”.*

Non-sampling error is however, not restricted to small businesses. For example, a further form of non-sampling error arises from the adoption of a strategy for the imputation/estimation of values for non-responding businesses. This is applicable to businesses of all sizes and is more significant for larger businesses – where the statistical units that perform larger amounts of R&D are generally classified. The methodology adopted for the current survey is based on allocating average values for these non-respondents – a reasonable strategy in many situations – but which may not work as well in this case because a lot of the non-responding businesses may not be R&D performers. An internal report prepared in Statistics New Zealand a year or so ago concluded that it could be more appropriate to apply an “historic” methodology for large R&D firms, in which the imputation is based on other facts known about the non-respondent, most importantly their previous level of R&D performance. Statistics New Zealand intend to consider this approach before the 2006 round of surveys.

A further difference between the methodologies adopted for the 2004 sampling approach, based on the Statistics New Zealand Business Register, and the previous list-based approaches lies in the detection of more firms to be included in the surveys in the strata designed to be fully enumerated. The collection of data from these firms, or in some cases the imputation/estimation for them based on the average value methodology, has resulted in an increase to the statistical aggregates derived from the survey compared to previous years. To the extent that these new units have been included in the results from the 2004 survey, that survey will necessarily be placed at a higher level than the results obtained from previous surveys. This does not mean that the level estimates from the 2004 survey are necessarily worse than previous results; in fact they may be better. However, it does mean that the estimate of change in level derived by comparing the 2004 survey result to the 2002 survey result will not be as good as it might.

## CONCLUSIONS

### FIRMS WITH LESS THAN 10 EMPLOYEES

The results for the two smallest size categories (less than 2 employees, and 2 – 10 employees) are unstable as a result of the high sampling errors and the, potentially worse, non-sampling errors. Unfortunately, there is no way of easily quantifying the size of the non-sampling errors. Thus, MoRST has not included them in the survey results used in the *Decade in Review*. Hence the published series will (in general) exclude firms with less than 10 employees – for all years included in the time series.

The one exception to this rule is in respect of the Scientific Research industry – an industry in which we could expect a much greater propensity to perform R&D and that is likely to keep much better records in respect of that R&D. This industry is also in the fully enumerated category and so statistics for it not subject to sampling error.

It is important to note that the general exclusion of firms with less than 10 employees from the statistical series does not mean that firms of this size do not perform any R&D – merely that we are unable to measure it with sufficient precision.

The impact of this change is to reduce the total size of the series is shown in Table 2.

TABLE 2. IMPACT OF OMISSION OF FIRMS WITH LESS THAN 10 EMPLOYEES

1994	- \$ 21 m
1996	- \$ 21 m
1998	- \$ 22 m
2000	- \$ 25 m
2002	- \$ 61 m
2004	- \$ 93 m

Note that these numbers are smaller than those shown in the previous Table 1 because that table includes the contribution of small businesses in the Scientific Research industry.

As an aside, it is worth noting that the dropping of firms of this size from future surveys could potentially have a further benefit to both MoRST and Statistics New Zealand in that it will reduce the cost of undertaking the R&D survey. Based on our results, only less than one in 100 firms of this size perform R&D. What this means is that, if a strictly random sampling technique is adopted, for every 100 firms of this size surveyed, on average 99 will report zero R&D. So, the collection cost for that group in terms of effective response and contribution to overall aggregates is not warranted.

Of course the survey is likely to attempt to reduce this inefficiency by adopting a stratification process that enables the better identification of small R&D performers.

It is also worth noting that the adoption of a cut-off of 10 employees brings these survey results into line with the scope of the 2003 Innovation Survey and the 2005 Business Operations Survey.

## FIRMS WITH 10–50 EMPLOYEES

The data series included in Table 1 also indicates significant instability in the group of firms that have 10–50 employees.

However, this group has a much lower sampling error (9%) because of the higher sampling fraction adopted. They are also likely to be subject to lower non-sampling errors – being larger, more research intensive and spending larger amounts of money on R&D, they are more likely to keep better records to help estimate the value of R&D performed in the firm. Larger firms also have a greater propensity to perform *Frascati Manual* R&D. As a group, therefore, they are likely to have smaller non-sampling errors.

On the basis of the lower sampling and non-sampling errors and their contribution to the overall totals, MoRST has concluded that this group should be retained in our statistics. Having reached this conclusion, it then becomes important to assess the adequacy of the time series for that group as a measure of the change in level over time.

It is fairly clear that the level of expenditure being recorded in 1996–2000 (of around \$50m) is inconsistent with the more recent figures – the earlier figures appear to be too low as an estimate of the total population of firms of this size. The doubling of the figure for 2002 seems to reflect the fact that the list based system may not have been working all that well for this size group. It is therefore appropriate for the benchmark level for this group to be established at the higher level recorded in 2002 and to apply adjustments to previous years' survey results based on the comparability bridge factors estimated from the 2002 survey.

On the other hand, an inspection of the larger reported values in respect of this group of firms in 2004, and the large (39%) allowance for weighting (as estimated by the difference between unweighted and weighted values) suggests that the current estimate of \$200m for 2004 may be too high. By way of comparison, the weighting factor for this group in the 2002 survey was 14%.

It was therefore decided to reduce the 2004 estimate by an amount determined by estimating the break created by the methodological change for this size group. Statistics New Zealand have reported that it is impossible to precisely measure the break created by the new methodology – which as discussed earlier can come from the sampling approach, the change in population of firms

included in the survey, the imputation scheme or any of the other methodological changes alluded to by Statistics New Zealand in the 2004 survey report.

One possible way to **estimate** the break in comparability created by the sampling approach is by looking at the differences between the weighted and the unweighted estimates for businesses included in strata in which sampling has been introduced. (The unweighted estimates refer to the data actually reported by sample respondents; the weighted estimates refer to the contribution that those reported values are having on the statistical aggregates.) It is much harder to be precise with a measure of the methodological change for the other contributing factors outlined earlier. These, of course, could come from either the sampled strata or those strata that are (supposedly) fully enumerated. For this group, it is proposed to assume that half of the difference between the unweighted and weighted estimates is due to a methodological change. The use of a 50% factor is merely a “guesstimate” – with the middle of the road figure being chosen to try to minimize the error in the estimate of the methodological change from this source.

There are two impacts on the 10 – 50 employee size group. These are as a result of the back-casting in 1994–2000 for the population increase detected in the 2002 survey and in 2004 for the exclusion of the impact of methodological change in that survey.

The effect of the proposed changes on published data for the 10-50 employee size group is shown in Table 3.

TABLE 3. IMPACT OF ADJUSTMENT TO FIRMS WITH 10–50 EMPLOYEES

1994	+ \$ 9 m
1996	+ \$ 17 m
1998	+ \$ 19 m
2000	+ \$ 21 m
2002	no effect
2004	– \$ 40 m

#### FIRMS WITH 50+ EMPLOYEES

Similar considerations to those for the 10 – 50 employee group could easily lead to the adoption of a similar methodology for this size group. However, it is important to note that there is very little sampling in this group – thus the impact of the implementation of the sampling approach should be minimal. Hence sampling errors are less of a problem. Some of the other factors affecting non-sampling errors – such as the detection of R&D performing businesses that would not have been detected under a list based system – may still apply but are probably not of the same significance as for the 10–50 employee size group. Hence one would expect the impact of non-sampling errors to

be comparatively smaller than for the 10–50 size group. However, it is not possible to say how much smaller.

In the absence of any accurate information on the size of these impacts, no adjustment was made for this methodological change. Such an action is likely to mirror the treatment of this group in future R&D surveys in which a full enumeration is expected to apply. Clearly the estimate of a zero impact for methodological change will be an understatement but probably not a significant one.

It is however appropriate to make adjustments to the series prior to 2002 for the 50+ employee size group of firms for the increased population detected as part of the 2002 survey – as there were some new R&D performing firms detected. Hence an adjustment factor was applied for years prior to 2002 derived from the 2002 data supplied by Statistics New Zealand.

For this size group of businesses, the back-casting of data for 1994 – 2000 is shown in Table 4.

TABLE 4. IMPACT OF ADJUSTMENT TO FIRMS WITH 50+ EMPLOYEES

1994	+ \$ 33 m
1996	+ \$ 28 m
1998	+ \$ 44 m
2000	+ \$ 45 m

#### THE TREATMENT OF UNITS IN THE SCIENTIFIC RESEARCH INDUSTRY

Over the past few surveys, a number of business units that have been classified to industry by Statistics New Zealand (on the basis of their predominant activity) have been subsequently recoded to an industry considered to be the one benefiting from that research. Prior to the publication of each of the survey results, the specific units to be reclassified have been agreed by Statistics New Zealand and MoRST.

In this analysis, it has been decided not to adopt that procedure. Each year of the series has been treated in a consistent manner. The units that were recoded in the 2004 survey have been returned to their selection industry. Data for each of these units in earlier years has also been reclassified, where necessary, to that same industry. This has ensured consistent treatment over the course of the surveys.

This changed procedure has been made for two main reasons. First, the treatment in this publication is consistent with the *Frascati Manual* which sets down guidelines for the conduct and reporting of R&D surveys. Secondly, the treatment of statistical units in this way ensures that the

results will be consistent on an industry basis with all other statistics classified to industry using the Stats New Zealand Business Register.

It should be noted that this procedure does not deny the interest in producing statistics which better describe the use of the R&D performed in New Zealand. However, MoRST now believes that such a need should be met by using other classifications available to provide that measure, most notably by using the socio-economic objective classification. It does not feel that it should potentially invalidate the use of a “pure” industry classification. As noted earlier, this is also the position taken in the *Frascati Manual*.

The impact of these changes is to merely reclassify significant amounts of R&D to the Scientific Research industry which will be separately identified in the *Decade in Review*. There will be corresponding drops in the other industries identified in this report. The effects are shown in Chart 2 below.

## THE RESULTS OF THE IMPLEMENTATION

As illustrated by Charts 1 and 2:

- the changes in the published levels of R&D expenditure for 1994, 1996, 1998 and 2000 have been increased because the impact of the downward effect created by the dropping of businesses with less than 10 employees (in all industries except the Scientific Research industry) has been more than offset by the impact of the upward effect of increasing the population size for larger businesses detected in the 2002 survey;
- The 2002 published level of R&D expenditure has been decreased because of the exclusion of firms with less than 10 employees (in all industries except the Scientific Research industry); and
- The published level for 2004 has decreased because of both the exclusion of the firms with less than 10 employees (in all industries except the Scientific Research industry) and the allowance made for the methodological change in the 2004 survey. The former has contributed approximately 70% of this adjustment.

CHART 2. COMPARISON OF R&D EXPENDITURE USING REVISED COMPARABLE SERIES AND ORIGINAL PUBLISHED SERIES, BY INDUSTRY

