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# Understanding R&D performance: A note on a new OECD indicator

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# Introduction

This paper deals with various technical issues relating to the use of R&D statistics. But these technical issues are of considerable importance in understanding R&D performance, and therefore in identifying policy problems and policy objectives. The basic problem follows from the use of 'R&D intensity' - meaning the R&D/Value Added or R&D/Sales ratio - as an overall indicator for the manufacturing sector of the economy, or for the economy as a whole. This particular measure has become extremely popular as an overall performance indicator, and is frequently used by policymakers, especially for international comparisons. However the indicator has a serious weakness, which is that it reflects not just R&D performance, but also the industrial structure in which R&D is carried out. So the indictor cannot be used - as it frequently is - simply as a measure of relative R&D strength.

The OECD has recently attempted to correct for these problems, by developing and indicator variously known as the OECD STIRD (*Structural indicator of R&D*) or STIBERD (*Structural indicator of business expenditure on R&D*) indicator. This note discusses these indicators, and argues that they continue to have significant weaknesses because they do not adequately reflect the industrial structural component of R&D intensity. The discussion here is based on two OECD documents. One is *Manufacturing Performance: A Scoreboard of Indicators*[1], where the indicator is briefly explained and some empirical applications are presented. The other is the STAN indicator note 1 (draft), 'Comparing Industrial R&D Performance. STIRD: A New S&T Indicator to Complement National R&D Expenditure as a Proportion of GDP plus National R&D Intensity Profiles'[2], where the indicator is discussed more thoroughly at a theoretical level.

In the STAN indicator note a new S&T indicator of industrial R&D performance is presented. The indicator is called STIRD, for Structural Indicator of R&D. It is constructed to take explicit account of 'the different industrial structures of different countries'.

STIRD is intended to be a complement to GERD/GDP, i.e. gross expenditures on R&D as a proportion of GDP, which is 'the most widely used indicator of aggregate (i.e. economy-wide) technological performance' (p. 1). A basic problem with the GERD/GDP indicator, however, is precisely that it does not take account of differences in industrial structure across countries. Given the fact that R&D intensities vary considerably across industries, the GERD/GDP indicator will to a large extent reflect simply the industrial structure of a given country, rather than how well it performs technologically in the industries that it actually has, i.e. in the production it actually engages in. Or, more accurately, it will always reflect both these aspects, but it will not tell us how much is due to the one and how much to the

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1 OECD, *Manufacturing Performance: A Scoreboard of Indicators*, OECD Documents, Paris: OECD 1994, pp. 51-57.

2 STAN indicator note 1 (draft), 'Comparing Industrial R&D Performance. STIRD: A New S&T Indicator to Complement National R&D Expenditure as a Proportion of GDP plus National R&D Intensity Profiles', OECD, DSTI/STIID, June 1991.

other of these two components. (Of course, these two components may be opposite in sign, so to speak: a 'favourable' industrial structure may be combined with a 'bad' performance in the different industries, or vice versa). It is, for instance, quite conceivable that one country can have a higher R&D intensity (have a 'better technological performance') than another country in every single industry, and nevertheless, owing to a 'less favourable' industrial structure, have a lower GERD/GDP figure than this other country. (We will here not go into a further discussion of the strengths and weaknesses of R&D intensity as an indicator of 'technological performance'.)

# The STIRD indicator

Let us now see how the STAN indicator note constructs the STIRD indicator. First, total production of a given country is divided into the sum of the production of a given number of industries. Second, there is defined a group of countries which are to enter into the comparison. Next, we look at each individual industry separately. We start with industry no. 1 and calculate the R&D intensity of this industry, defined as R&D expenditures as a proportion of value added in the industry, in each of the countries that we compare. We then calculate the *average* R&D intensity of industry no. 1 over all these countries, where this average is a *simple* average, i.e. all countries are weighted equally. In the same way, we go on to define the average R&D intensities of all the other industries over this particular group of countries.

To calculate the score on the STIRD indicator for a given country, we take, for each individual industry, the *ratio* of the R&D intensity of the country in question to the *average* R&D intensity of the industry over the countries which enter into the comparison. For each industry, that is, we calculate the *relative* R&D intensity of the country in question when compared to this average. We then go on to calculate the *average* of these relative R&D intensities over all industries, where the industries are weighted by their output share (as measured by value added). STIRD of a given country, then, is the weighted sum over all industries of these relative R&D intensities, when the weights are defined by the output shares of the individual industries.

In mathematical terms, STIRD of a given country k is defined by

$$STIRD_k = \sum_i \left\{ \frac{RI_{i,k}}{av(RI_i)_G} \cdot \frac{VA_{i,k}}{GDP_k} \right\}$$

where, for $RI_{i,k}$ is the R&D intensity of industry i for country k, $av(RI_i)_G$ is the average R&D intensity of industry i over the group of countries G, and $\frac{VA_{i,k}}{GDP_k}$ is the share of the production of industry i in the GDP of country k.

Let us take an example. We start with the R&D intensity of *total* domestic production. This total may refer to the GDP, in which case this intensity is expressed by GERD/GDP, or it may for instance refer to total *manufacturing* production of a country, in which case the R&D intensity will be expressed by total R&D expenditures in the manufacturing sector as a proportion of total value added of the manufacturing sector. Instead of GERD/GDP, let us use $\frac{R\&D_{TOT}}{VA_{TOT}}$ as a more general expression of the R&D intensity of total production, where $R\&D_{TOT}$ denotes total R&D expenditures and $VA_{TOT}$ denotes total value added. This is also in line with how the OECD itself envisages that the indicator in practice is going to be used. As stated in the STAN indicator note (p. 3): ‘In practice, internationally comparable data for R&D expenditures are not available for agriculture, mining and services. ....

International comparisons at the industry level are therefore confined to business enterprise expenditure on R&D within manufacturing. Consequently, the sum over industries in STIRD must be restricted to manufacturing and GDP replaced by manufacturing value added. The resultant indicator is thus a measure of *relative manufacturing industrial R&D performance* and will be called *manufacturing STIBERD.*'[3]

Now, let us imagine two countries, country A and country B, which have the same R&D intensity of total production, but with different industrial structures. To give a simple illustration, we make the assumption that the economies in question consist of only two industries, industry 1 and industry 2. Industry 1 is an industry which typically is characterized by low R&D intensity, while industry 2 typically is characterized by high R&D intensity.

$R\&D_{TOT}$ is the sum of R&D expenditures in industry 1 and R&D expenditures in industry 2, $R\&D_1 + R\&D_2$ . Consequently, we have

$$\frac{R\&D_{TOT}}{VA_{TOT}} = \frac{R\&D_1 + R\&D_2}{VA_{TOT}} \ .$$

Transforming this expression, we get

$$\frac{R\&D_{TOT}}{VA_{TOT}} = \left(\frac{R\&D_1}{VA_1} \cdot \frac{VA_1}{VA_{TOT}}\right) + \left(\frac{R\&D_2}{VA_2} \cdot \frac{VA_2}{VA_{TOT}}\right)$$

Since the ratio of R&D expenditures to value added is the R&D intensity (RI), we have

$$\frac{R\&D_{TOT}}{VA_{TOT}} = \left(RI_1 \cdot \frac{VA_1}{VA_{TOT}}\right) + \left(RI_2 \cdot \frac{VA_2}{VA_{TOT}}\right) ,$$

or, in the general case with n industries,

$$\frac{R\&D_{TOT}}{VA_{TOT}} = \sum_i \left\{RI_i \cdot \frac{VA_i}{VA_{TOT}}\right\} ,$$

i.e. $\frac{R\&D_{TOT}}{VA_{TOT}}$ is the sum over all industries (in this case *both* industries) of the products of the R&D intensity and the share of total output of each industry.

Let us suppose that both country A and country B have an R&D intensity of total production of 5 %. However, country A has a higher R&D intensity than country B in both industry 1 and industry 2, 1.875 % as against 1.0 % in industry 1, 17.5 % as against 14.33 % in industry 2. On the other hand, country B has a higher share of its

[3] italics in the original.

production in the high R&D intensity industry than country A. Country B has 70 % of total output in industry 1 and 30 % of total output in industry 2, while for country A the shares of industry 1 and industry 2 are 80 % and 20 %, respectively.

Thus, we can summarize the R&D intensities of total production of the two countries in the following way:

Country A: $\dfrac{R\,\&\,D_{TOT}}{VA_{TOT}} = (0.01875 \cdot 0.8) + (0.175 \cdot 0.2) = 0.05$

Country B: $\dfrac{R\,\&\,D_{TOT}}{VA_{TOT}} = (0.01 \cdot 0.7) + (0.1433 \cdot 0.3) = 0.05$

The two countries have the same R&D intensity of total production. But since country A has a higher R&D intensity than country B in both industries, we would intuitively say that country A has a higher R&D intensity than country B when we take industrial structure into account. In other words, we would expect country A to have a higher STIRD than country B.

This is exactly what we get (given reasonable assumption of what the average R&D intensities of the two industries are). Let us suppose that in a wider group of which serves as a basis for the comparison, the average R&D intensity of industry 1 is 1 % while the average R&D intensity of industry 2 is 15 %. Recall that STIRD of country k is given by

$$STIRD_k = \sum_i \left\{ \frac{RI_{i,k}}{av(RI_i)_G} \cdot \frac{VA_{i,k}}{VA_{TOT\,k}} \right\} .$$

We then get:

Country A: STIRD = $\left( \dfrac{0.01875}{0.01} \cdot 0.8 \right) + \left( \dfrac{0.175}{0.15} \cdot 0.2 \right) = 1.73$

Country B: STIRD = $\left( \dfrac{0.01}{0.01} \cdot 0.7 \right) + \left( \dfrac{0.1433}{0.15} \cdot 0.3 \right) = 0.99 .$

Here the difference in industrial structure seems to be taken into account in the following way: Both countries have the same R&D intensity of total production. However, country B has an industrial structure which is more favourable from the point of view of having a high R&D intensity of total production than country A. This idea of how favourable an industrial structure is to a high R&D intensity of total production can be given a fairly precise meaning. It can be expressed by the R&D intensity of total production that a country *would have had* if it had the industrial structure that it actually has, but in each single industry had the average R&D intensity of the industry concerned over the countries which are being compared. This ’structural element’ must somehow be ’subtracted’ if we want to take into account the industrial structure of a country when we evaluate its R&D intensity performance: Taking this 'structural disadvantage' into account, country A 'really' does better than country B.

However, in the STAN indicator note there is not only mention of taking differences in *industrial structure* into account. STIRD is also said to reflect the *allocation* of R&D expenditures across different industries (p. 2).

And, in fact, even if two countries have the same R&D intensity of total production *and* the same industrial structure, *they may still have different STIRD values*. To give a simple example, let us once again imagine two countries, country A, which is the same as above, and country C. We still think of the economies as divided into only two industries.

Both countries, then, have the same R&D intensity of total production, 5 %. Both also have the same industrial structure, the industrial structure of country A in the example above. But country C has a *lower* R&D intensity than country A in industry 1, namely 1.25 %, and a *higher* R&D intensity than country A in industry 2, namely 20 %.

Let us summarize the R&D intensities of total production of the two countries in the same way as above:

Country A: $\frac{R\,\&\,D_{TOT}}{VA_{TOT}} = (0.01875 \cdot 0.8) + (0.175 \cdot 0.2) = 0.05$

Country C: $\frac{R\,\&\,D_{TOT}}{VA_{TOT}} = (0.0125 \cdot 0.8) + (0.2 \cdot 0.2) = 0.05$

Then, let us calculate the STIRD values of the two countries:

Country A: STIRD = $\left(\frac{0.01875}{0.01} \cdot 0.8\right) + \left(\frac{0.175}{0.15} \cdot 0.2\right) = 1.73$

Country C: STIRD = $\left(\frac{0.0125}{0.01} \cdot 0.8\right) + \left(\frac{0.2}{0.15} \cdot 0.2\right) = 1.27$ .

We see that even though the two countries have the same R&D intensity of total production *and* the same industrial structure, country A nevertheless has a higher STIRD than country C. This should correspond to the case at the top of page 3 in the STAN indicator note, where it is said that what in our example corresponds to country A has a higher STIRD because 'it has a better R&D intensity performance in the industries that account for relatively large shares of its output.'

STIRD, then, is an S&T indicator which is developed to take explicitly account of the different industrial structures of different countries. However, it appears that STIRD does not only take account of differences in industrial structure across countries, but also of differences in allocation of R&D expenditures across industries. Even if two countries have the same R&D intensity of total production and the same industrial structure, they will in general not have the same STIRD because STIRD also will depend upon how the R&D expenditures are allocated across the different industries.

Clearly, these are separate dimensions. But what is the relationship between them? Imagine we have two countries with the same R&D intensity of total production but with very different STIRD values. Does this primarily reflect a difference in industrial structure between the two countries, or does it reflect a difference in the allocation of R&D expenditures across industries? Or rather, how much of the difference in STIRD is due to a difference in industrial structure and how much is due to a difference in the allocation of R&D expenditures across industries? Obviously, just looking at the STIRD values will not tell us this. And is it even possible that these two dimensions might work in opposite directions, so that two countries which had both the same R&D intensity of total production *and* the same STIRD nevertheless might differ considerably both in industrial structure *and*, but in the 'opposite' direction, in the allocation of R&D resources across industries?

It is thus not altogether clear what exactly the STIRD indicator measures. In order to understand the issues involved better, we will in the following investigate the indicator more closely. To anticipate, we shall see that there are some problems with this indicator, and that the interpretation it is given in the STAN indicator note is slightly inaccurate. Consequently, we will also have to revise the interpretation of the examples given above.

Let us take a closer look at the STIRD indicator, then.

As above, we suppose as given a group of countries across which an *average* R&D intensity is defined for each individual industry. Let us look at a particular country k in this group. This country has a certain amount of total expenditures on R&D, and accordingly a certain R&D intensity of its total production (e.g. GERD/GDP). Let us assume these *total* R&D expenditures, and consequently this R&D intensity of *total* production, as given.

Now, given these total R&D expenditures, what kind of distribution of these R&D resources across industries will give a high STIRD value and what kind of distribution will give a low STIRD value? A result which we may find slightly curious is that one will *always* get a higher STIRD value by reallocating R&D expenditures *from* an industry with a *higher to* an industry with a *lower average* R&D intensity. That is, given that the STIRD indicator is intended as a measure of R&D performance, one would according to this indicator always 'perform better' if one does this.

It is easy to show this. Let us start with mathematical expression of STIRD, using the notation in the STAN indicator note:

$$STIRD = \sum_i \left\{ \frac{RI_i}{av(RI_i)_G} \cdot \frac{VA_i}{VA_{TOT}} \right\}$$

Since we are here only concerned with one country, we choose to omit the subscript *k*. We also choose to substitute GDP by the more general total value added, denoted by $VA_{TOT}$ , which may refer both to GDP or to some other total production, e.g. total *manufacturing* production of a country.

Now, the R&D intensity of a given industry i, $RI_i$ , is defined by the ratio of the R&D expenditures of the industry to the value added of the industry, $\frac{R\&D_i}{VA_i}$ , where the R&D expenditures of industry i are denoted simply by $R\&D_i$ .

Substituting the expression $\frac{R\&D_i}{VA_i}$ for $RI_i$ , we get

$$STIRD = \sum_i \left\{ \frac{\frac{R\&D_i}{VA_i}}{av(RI_i)_G} \cdot \frac{VA_i}{VA_{TOT}} \right\}$$

Multiplying both the nominator and the denominator of the first fraction by $VA_i$ , we get

$$STIRD = \sum_i \left\{ \frac{R\&D_i}{av(RI_i)_G \cdot VA_i} \cdot \frac{VA_i}{VA_{TOT}} \right\}$$

which reduces to

$$STIRD = \sum_i \left\{ \frac{R\&D_i}{av(RI_i)_G} \cdot \frac{1}{VA_{TOT}} \right\}$$

and we get

$$STIRD = \frac{1}{VA_{TOT}} \cdot \sum_i \frac{R\&D_i}{av(RI_i)_G}$$

Now, let us imagine two industries, industry *e* and industry *f*. The *average* R&D intensity (i.e. over the countries which enter the comparison) of industry e, $av(RI_e)_G$ , is *lower* than the *average* R&D intensity of industry f, $av(RI_f)_G$ . In situation *1* the R&D expenditures of industry e is $R\&D_e$ , while the R&D expenditures of industry f is $R\&D_f$ . In situation 1, we then get

$$STIRD_I = \frac{1}{VA_{TOT}} \cdot \left\{ \frac{R\&D_1}{av(RI_1)_G} + \ldots + \frac{R\&D_e}{av(RI_e)_G} + \frac{R\&D_f}{av(RI_f)_G} + \ldots + \frac{R\&D_n}{av(RI_n)_G} \right\},$$

where situation 1 is denoted by the subscript I.

We now reallocate R&D resources of an amount *a* from industry f to industry e. STIRD in situation *2* then becomes

$$STIRD_{II} = \frac{1}{VA_{TOT}} \cdot \left\{ \frac{R\&D_1}{av(RI_1)_G} + \ldots + \frac{R\&D_e + a}{av(RI_e)_G} + \frac{R\&D_f - a}{av(RI_f)_G} + \ldots + \frac{R\&D_n}{av(RI_n)_G} \right\},$$

where the subscript II denotes situation 2.

Our assertion above implies that STIRD in situation 2 must be higher than STIRD in situation 1, or

$$STIRD_{II} - STIRD_{I} > 0 \ .$$

This gives

$$\frac{1}{VA_{TOT}} \cdot \left\{ \frac{R\&D_1}{av(RI_1)_G} + \ldots + \frac{R\&D_e + a}{av(RI_e)_G} + \frac{R\&D_f - a}{av(RI_f)_G} + \ldots + \frac{R\&D_n}{av(RI_n)_G} \right\}$$
$$- \frac{1}{VA_{TOT}} \cdot \left\{ \frac{R\&D_1}{av(RI_1)_G} + \ldots + \frac{R\&D_e}{av(RI_e)_G} + \frac{R\&D_f}{av(RI_f)_G} + \ldots + \frac{R\&D_n}{av(RI_n)_G} \right\} > 0 \ .$$

Multiplying both sides of the inequality by $VA_{TOT}$, we get, since $VA_{TOT}$ is necessarily positive,

$$\frac{R\&D_1}{av(RI_1)_G} + \ldots + \frac{R\&D_e + a}{av(RI_e)_G} + \frac{R\&D_f - a}{av(RI_f)_G} + \ldots + \frac{R\&D_n}{av(RI_n)_G}$$
$$- \frac{R\&D_1}{av(RI_1)_G} - \ldots - \frac{R\&D_e}{av(RI_e)_G} - \frac{R\&D_f}{av(RI_f)_G} - \ldots - \frac{R\&D_n}{av(RI_n)_G} > 0$$

This reduces to

$$\frac{R\&D_e + a}{av(RI_e)_G} + \frac{R\&D_f - a}{av(RI_f)_G} - \frac{R\&D_e}{av(RI_e)_G} - \frac{R\&D_f}{av(RI_f)_G} > 0$$

which gives

$$\frac{R\&D_e}{av(RI_e)_G} + \frac{a}{av(RI_e)_G} + \frac{R\&D_f}{av(RI_f)_G} - \frac{a}{av(RI_f)_G} - \frac{R\&D_e}{av(RI_e)_G} - \frac{R\&D_f}{av(RI_f)_G} > 0$$

We are consequently left with

$$\frac{a}{av(RI_e)_G} - \frac{a}{av(RI_f)_G} > 0$$

or

$$\frac{a}{av(RI_e)_G} > \frac{a}{av(RI_f)_G}$$

We now multiply each side of this inequality by $\frac{av(RI_e)_G \cdot av(RI_f)_G}{a}$. Since this expression is positive, we get

$$av(RI_f)_G > av(RI_e)_G \ ,$$

which is precisely the condition we presupposed.

In other words, given the *total* R&D expenditures of a country (or of the relevant sector of the economy, e.g. the manufacturing sector), STIRD will *always* be higher if R&D resources are reallocated *from* an industry with a higher *average* R&D intensity *to* an industry with a lower average R&D intensity.

Let us now look closer into what kind of consequences this is likely to have. As we have said, the STIRD indicator will reflect both the proportion of total R&D expenditures to total production and how these R&D expenditures are distributed across industries. It is the latter property which particularly concerns us here. The basic point of departure is that R&D intensities vary considerably across industries. Some industries have high R&D intensities, others have low, still others are in-between.

Now, let us suppose that it is a fairly common situation that the R&D resources of a country are too heavily concentrated in the high R&D intensity industries. Given total R&D expenditures, it would be rational to reallocate *some* of these resources away from the high R&D intensity industries and into the low intensity industries. In this situation, the STIRD indicator would seem to work well: Given total R&D expenditures, if some R&D resources are redistributed away from high R&D intensity industries and into low intensity industries, STIRD will rise.

But let us now reflect on what a rational or reasonable distribution of R&D expenditures across industries could be expected to look like. Surely, there is absolutely no reason to believe that it would be an *equal* distribution in the sense that R&D intensities were the same in all industries. Even a rational distribution of R&D resources inevitably would have to be characterized by considerable differences in R&D intensity across industries, reflecting considerable inter-industry differences in conditions of production, market conditions, etc.

Now, the situation we postulated above, in relation to which we said that the STIRD indicator would seem to function well, was one where the distribution of R&D expenditures quite generally was considerably biased in favour of the high R&D intensity industries. This, of course, would have to mean a distribution which emerges as biased in this direction when measured against a hypothesized rational distribution of R&D resources across industries, i.e. when measured against a distribution which itself would have to be very uneven.

But suppose instead that the state of having a distribution of R&D resources which is *biased* in favour of the high R&D intensity industries (i.e. a distribution which is *more* unequal in this direction than would be rational), even if frequently met with, is not an exclusively dominating state of affairs. Suppose, for instance, that this is the situation in perhaps the majority of countries, but that in some countries this distribution is quite reasonably balanced and that a few countries even have a distribution which is biased too much in favour of the *low* R&D intensity industries. If this should be the case, and precisely to the extent that some countries should actually have a distribution of R&D resources which is biased in favour of the *low* R&D intensity industries when measured against a hypothetical rational distribution, the STIRD indicator may be quite misleading. If we once again imagine that we hold total R&D expenditures to total production constant, the countries which have a distribution of R&D resources too much in favour of the low R&D intensity industries will get a *higher* STIRD than if they had a reasonable distribution. Given the ratio of total R&D expenditures to total production, STIRD simply does *not* reach its maximum when the distribution of R&D expenditures across industries is reasonably balanced. It will not even reach its maximum when this distribution is perfectly equal in the sense that all industries have the same R&D intensity. On the contrary, it will not reach its maximum until *all* the R&D expenditures of the country are concentrated in *one* single industry, namely the industry with the lowest *average* R&D intensity (i.e. across the countries which enter the comparison. Now, of course, in this case the R&D intensity in this industry would probably rise so much that the average R&D intensity across the group of countries would rise as well. But this is an extreme, even absurd, limiting case. Quite generally, we will think of the average R&D intensity across the group of countries as given).

Let us sum up this point. The STIRD indicator reflects both the R&D intensity of total production, i.e. the ratio between total R&D expenditures and total production, and the distribution of R&D expenditures across industries. The relationship between the R&D intensity of total production and STIRD is straightforward: given the distribution of R&D expenditures, STIRD will rise when total R&D expenditures rise. What we have considered is how the STIRD indicator varies with the *distribution* of R&D expenditures across industries, holding total R&D expenditures constant. We found that the higher the share of R&D expenditures in industries with a *low average* (i.e. across the group of countries) R&D intensity is, the higher STIRD will be: STIRD will always rise when R&D expenditures are redistributed from an industry with a higher to an industry with a lower average R&D intensity.

We now want to draw attention to an important implication of this conclusion. That STIRD *always* will rise when R&D expenditures are redistributed from an industry with a higher to an industry with a lower average R&D intensity means that this will be the case *irrespective of the share of each of these two industries in the total production of the country*. Whether the low R&D intensity industry in question accounts for a large or a small share of total output of the country is of no consequence.

For instance, let us again postulate a country k belonging to a group of countries G, and let us focus on two industries e and f out of a total of n industries. As above, industry f has a higher average R&D intensity (across the group of countries) than industry e. Now, let us suppose that industry f is a relatively high R&D intensity industry, with an average R&D intensity of 10 %. It is also a very important industry in country k, accounting for approximately 10 % of its manufacturing production. However, the R&D performance of the industry in country k is not at all satisfactory. The R&D intensity is well below average at only 7 %. Industry e, on the other hand, is typically a low R&D intensity industry, with an average R&D intensity across the group of countries of only 0.5 %. Also, in our country k it is a far less important industry in terms of output than industry f, accounting for less than 3 % of total manufacturing production of this country. However, the R&D performance of this industry in country k is quite satisfactory. The R&D intensity industry e in country k is 0.9 %, nearly twice the average across the group of countries. Nevertheless, *it will still be the case that country k will get a higher STIRD if R&D resources are reallocated from the high R&D intensity industry f to the low R&D intensity industry e*. Whether the high intensity industry is actually far more important in terms of output in country k than the low intensity industry, or whether the low intensity industry already has a more than satisfactory R&D performance whereas in the high intensity industry R&D performance is far behind average, makes no difference. This seems quite illogical, and surely must be contrary to the intentions behind the construction of the STIRD indicator.

In order better to understand what is happening here, let us now go back to the definition of the STIRD indicator. In mathematical terms, we saw that STIRD of a given country was defined by

$$STIRD = \sum_i \left\{ \frac{RI_i}{av(RI_i)_G} \cdot \frac{VA_i}{VA_{TOT}} \right\}.$$

Here the term $\frac{VA_i}{VA_{TOT}}$ represents the industrial structure of the country in question. However, we also saw that this expression could be transformed, so that STIRD also could be written as

$$STIRD = \frac{1}{VA_{TOT}} \cdot \sum_i \frac{R\&D_i}{av(RI_i)_G} \ .$$

What is worth noting here is that in this expression *the actual industrial structure of the country is totally absent*, so to speak. STIRD turns out to depend only on the R&D expenditures in each industry, the *average* (across the group of countries) R&D intensity in each industry, and total production of the country. It seems that, contrary to what was claimed to be the rationale behind the construction of the indicator, STIRD does *not* take explicitly account of differences in industrial structure across countries.

Of course, the industrial structure of the country will be one component which *influences* the STIRD value. The important point, however, is that the industrial structure is not *explicitly* taken account of.

To see this more clearly, let us take as an example the indicator which lies behind the development of the STIRD indicator in the first place, namely the traditional $\frac{GERD}{GDP}$ indicator, or, in our more general terminology, $\frac{R\&D_{TOT}}{VA_{TOT}}$. STIRD was developed as an 'improvement and complement to' this traditional indicator precisely because this indicator does not explicitly take account of the differences in industrial structure across countries.

But of course, this traditional indicator can also be written in a form which gives the impression that it, too, takes account of differences in industrial structure. In fact, as we showed above, we have

$$\frac{R\&D_{TOT}}{VA_{TOT}} = \sum_i \left\{ RI_i \cdot \frac{VA_i}{VA_{TOT}} \right\},$$

i.e. $\frac{R\&D_{TOT}}{VA_{TOT}}$ is the sum over all industries of the products of the R&D intensity of each industry and its share of total output. Again, the term $\frac{VA_i}{VA_{TOT}}$ represents the industrial structure of the country. But again, this only tells us that industrial structure is one of the components influencing the R&D intensity of total production. Since this term just disappears when the equation is transformed, industrial structure is, of course, not explicitly taken account of. It would seem that the same has to be said about the STIRD indicator.

What we would seem to have to demand of an indicator that claimed to take explicitly account of differences in industrial structure was that industrial structure was included in the indicator formula in such a way that it could not be eliminated simply by a transformation of the formula. We will come back to this further below.

But before we do that, we want to reconsider the examples we presented at the start of this note. There we imagined three countries, A, B and C, which all had the same R&D intensity of total production, namely 5 %. We summarized their R&D intensities in each industry, their industrial structures and their R&D intensity of total production in the following way:

Country A: $\frac{R\&D_{TOT}}{VA_{TOT}} = (0.01875 \cdot 0.8) + (0.175 \cdot 0.2) = 0.05$

Country B: $\frac{R\&D_{TOT}}{VA_{TOT}} = (0.01 \cdot 0.7) + (0.1433 \cdot 0.3) = 0.05$

Country C: $\dfrac{R\&D_{TOT}}{VA_{TOT}} = (0.0125 \cdot 0.8) + (0.2 \cdot 0.2) = 0.05$

We then calculated STIRD for each country:

Country A: STIRD = $\left(\dfrac{0.01875}{0.01} \cdot 0.8\right) + \left(\dfrac{0.175}{0.15} \cdot 0.2\right) = 1.73$

Country B: STIRD = $\left(\dfrac{0.01}{0.01} \cdot 0.7\right) + \left(\dfrac{0.1433}{0.15} \cdot 0.3\right) = 0.99$.

Country C: STIRD = $\left(\dfrac{0.0125}{0.01} \cdot 0.8\right) + \left(\dfrac{0.2}{0.15} \cdot 0.2\right) = 1.27$.

We see that country A has a higher STIRD than both country B and country C, although all countries have the same R&D intensity of total production. Comparing country A and country B, we said that since country A has a lower proportion of its production in the high R&D intensity industry than country B, it has a 'structural disadvantage' in relation to B when it comes to having a high R&D intensity of total production. Since the two countries nevertheless have the same R&D intensity of total production, country A is seen to have a better R&D intensity performance when differences in industrial structure are taken into account.

Comparing country A and country C, which in addition to having the same R&D intensity of total production also had the same industrial structure, we said that, quoting the STAN indicator note, country A had a higher STIRD than country C because country A 'has a better R&D intensity performance in the industries that account for relatively large shares of its output.'

None of these, however, are correct interpretations. This is *not* the way STIRD works. What is essential here, on the contrary, is the following:

For every 100 units of total output, each of our three countries uses 5 units in R&D expenditures. The distribution of these 5 units is 1.5 units in industry 1 and 3.5 units in industry 2 in country A, 0.7 units in industry 1 and 4.3 units in industry 2 in country B, and 1 unit in industry 1 and 4 units in industry 2 in country C. Given total R&D expenditures and total production, this distribution of R&D expenditures across industries is the only thing that affects STIRD, in the way that the country which distributes the greatest share of these R&D expenditures to the industry with the lowest *average* R&D intensity gets the highest STIRD, *quite irrespective of what its actual industrial structure is*. The actual industrial structure of each country does not affect STIRD at all.

Let us show this by means of yet another simple example. We postulate a country D which has the same R&D intensity of total production as the other countries, i.e. 5 %. It distributes its R&D expenditures across industries in the same way as country A does, i.e. out of 5 units of R&D expenditures, 1.5 units go to industry 1 and 3.5 units go to industry 2. However, it has an industrial structure which is quite 'the opposite' of country A's, with only 20 % of its production in the low average R&D intensity industry and the remaining 80 % in the high average R&D intensity industry. Given these presuppositions, country D's R&D intensity in each industry, industrial structure and total R&D intensity can be summed up in the following way:

Country D: $\frac{R\&D_{TOT}}{VA_{TOT}} = (0.075 \cdot 0.2) + (0.04375 \cdot 0.8) = 0.05$

As we see, country D has an abnormally high R&D intensity in the low R&D intensity industry, which however accounts for a small share of its total production, while it has an unusually low R&D intensity in the high R&D intensity industry, which accounts for a very large share of its total production.

Let us then calculate STIRD for country D:

Country D: STIRD = $\left(\frac{0.075}{0.01} \cdot 0.2\right) + \left(\frac{0.04375}{0.15} \cdot 0.8\right) = 1.73$

In accordance with what we have said, country D gets exactly the same STIRD as country A.

This also means that country D has a higher STIRD than both country B and country C, although all countries have the same R&D intensity of total production. However, the reasons that we gave when we tried to explain why *country A* got a higher STIRD than country B and country C, in terms of industrial structure and in terms of having 'a better R&D intensity performance in the industries that account for relatively large shares of its output', turn out not to be valid here at all. On the contrary, country D has a far more favourable industrial structure from the point of view of having a high R&D intensity of total production than any of the other countries, and it has a very poor R&D intensity performance in the industry which accounts for the dominant share of its total output. Given its industrial structure, country D has a no less than perverse distribution of its total R&D expenditures across industries. This, however, is not at all reflected in the STIRD indicator. Given the R&D intensity of total production and given the distribution of R&D expenditures across industries, STIRD will remain the same *no matter what the industrial structure of the country is*.

And, in fact, we have shown in a general way above that given the total R&D expenditures of a country, its STIRD will reach its maximum value when *all* the R&D expenditures are concentrated in the low average R&D intensity industry. In our example, given the average R&D intensity in each industry, and given an R&D intensity of total production of 5 %, the maximum value that STIRD can get is 5. This value it will get when all R&D expenditures are concentrated in industry 1, irrespective of whether industry 1 accounts for 99.5 % of total production or 0.5 % of total production (in which case the R&D intensity in this industry will be absurdly high). This is the way the STIRD indicator works.

However, what we have just said needs to be qualified somewhat. We have said that, contrary to what the STAN indicator note claims, the industrial structure of a country is *not* reflected in the STIRD indicator. The STAN indicator note interprets a high

STIRD value as expressing that the country in question has a good 'R&D intensity performance in the industries that account for relatively large shares of its output' (see for instance p. 3). We, on the other hand, have claimed that, given the R&D intensity of total production, the only thing that determines STIRD is the distribution of R&D expenditures across industries: the more of these R&D expenditures that belong to industries with a low *average* R&D intensity, the higher STIRD will be, irrespective of how large share of total output are accounted for by these industries.

Now, in all countries, although varying in degree from one country to another, one will find that R&D expenditures are very unevenly distributed across industries. Most of production is accounted for by industries with relatively low R&D intensities, while industries with high R&D intensities account for a relatively small share of production. Thus, if a country has a high STIRD compared to its R&D intensity of total production, this means that it has a relatively high share of its R&D expenditures in industries with a low *average* (across the group of countries) R&D intensity. But since relatively low R&D intensity industries tend to account for the larger share of total production, this means that there will be a tendency for countries which have a relatively high proportion of its R&D expenditures in low average R&D intensity industries also to have relatively high (given their R&D intensity of total production) R&D intensities in industries which account for a large share of total production.

Therefore, and here comes the qualification, *empirically* there will most likely be a tendency for the STIRD indicator to work the way that the STAN indicator claims it will. If a country has a high STIRD compared to its R&D intensity of total production, this means that it has relatively high R&D intensities in industries with low average R&D intensity. But precisely because of the tendency we noted above, there will be a tendency that this *also* means that it has relatively high R&D intensities in 'industries that account for relatively large shares of its output.'

However, this relationship is not in any way perfect. If total production is divided into many individual industries, there will be a number of low R&D intensity industries which account for a small share of total output, while some high R&D intensity industries may account for a quite large share of total output. Exactly how this will look will of course depend on how the industries are classified, for instance on how many categories there are. But in any case there will be ample scope for STIRD to take on values which are quite misleading in relation to what it is supposed to measure.

A high STIRD relative to R&D intensity of total production, then, may indeed reflect that the country in question has a good 'R&D intensity performance in the industries that account for relatively large shares of its output.' However, it may also to a large extent reflect unusually high R&D intensities in a small number of low average R&D intensity industries which together do not account for a very large share of total output. Thus, to what extent the STIRD indicator really measures what it is supposed to measure and to what extent it reflects something else will be an empirical question.

But anyway, the STIRD indicator is *not* sensitive to *differences* in industrial structure across countries. STIRD is meant to measure R&D intensity *performance* taking account of the distribution of R&D expenditures across industries. If one country has a larger share of its production in high (average) R&D intensity industries than another country, STIRD does *not* imply that the first country should have a higher share of its R&D expenditures in the high (average) R&D intensity industries than the second country, corresponding to the difference in industrial structure between the two countries. On the contrary, STIRD implies that both countries should allocate their R&D resources in the same way, namely by concentrating as large a share as possible of these resources in the low (average) R&D intensity industries.

It is also possible to think of another argument to the effect that STIRD *empirically* functions reasonably well, an argument which we have briefly alluded to at the beginning of this note. If one assumes that it quite generally is the case that the distribution of R&D resources is *too* unequal in favour of the high R&D intensity industries, so that a distribution which is too much in favour of the low R&D intensity industries will virtually never be found in real life, a reallocation of R&D resources from high R&D intensity industries to low R&D intensity industries will always be rational, irrespective of the industrial structure of the country in question. I.e., if in fact a distribution of R&D resources too much in favour of the low R&D intensity industries is virtually never reached, STIRD may function reasonably well even assuming that it does *not* take adequately account of differences in industrial structure across countries.

To tell whether this is a reasonable assumption or not we would have to have an idea of what a rational distribution of R&D expenditures across industries would look like. This would have to be based on a thorough investigation of production and market conditions in each individual industry. And here we would not only have to take account of in which industries the R&D is *performed*, but also in which industries the results of the R&D are realized, for instance in the form of productivity increases. R&D expenditures in one industry may result in the production of new machines that augment productivity in other industries which use these machines. This kind of inter-industry interaction may be crucial to consider if we are to get an adequate idea of what would be a rational distribution of R&D expenditures across industries.

However, for any given country, STIRD implies that the rational way to distribute R&D resources across industries would be to allocate as much as possible of these resources precisely to those industries where the other countries allocate *least* R&D resources. This seems a bit perverse, though. There probably are very good reasons for the distribution of R&D resources across industries being the way we almost invariably observe it, with large variations in R&D intensities from one industry to another, and with more or less the same industries having high, respectively low, R&D intensities in each case. Even if it may be reasonable to believe that there in many cases to some extent may be a too high concentration of R&D resources in high R&D intensity industries, with a tendency to a certain neglect of low R&D intensity industries, it nevertheless seems likely that a rational distribution of R&D resources across industries will not be too different from the kind of distribution that we in general actually observe. If this is indeed the case, it would seem that one cannot be so sure of virtually never meet with a distribution of R&D resources too much in favour of the low R&D intensity industries. And, as we showed above, to the extent that this actually happens, the STIRD indicator may be quite misleading.

# An alternative indicator

To help us see more clearly what is involved here, let us try to with a different indicator for adjusting manufacturing R&D intensity for differences in industrial structures across countries.

We choose to use an indicator which on the face of it looks very similar to the STIRD (or STIBERD) indicator, the only difference being that where the STAN indicator is based on the *ratio* of the R&D intensity of the country in question to the average R&D intensity across the group of countries in each industry, the indicator we propose here is based on the *percentage difference* between the R&D intensity of the country in question and the average R&D intensity across the group of countries in each industry. Let us denote this indicator by $STI_{diff}$ , for structural indicator of R&D expenditures based on percentage differences. In the notation of the STAN indicator note, we thus have

$$STI_{diff} = \sum_i \left\{ \left( RI_i - av(RI_i)_G \right) \cdot \frac{VA_i}{VA_{TOT}} \right\} .$$

For each industry, we take the difference between the R&D intensity of the industry of the country in question and the average R&D intensity of the industry over the group of countries. Then we multiply this difference with the share of total value added of the country in question accounted for by this industry. Lastly, we sum these weighted differences over all industries. If the country in question on (weighted) average has an R&D intensity *above* average in the individual industries, the indicator will be *positive*. If it on (weighted) average has an R&D intensity *below* average in the individual industries, the indicator will be *negative*.

Let us look closer at this expression. Multiplying by $\frac{VA_i}{VA_{TOT}}$ inside the parenthesis, we get

$$STI_{diff} = \sum_i \left\{ RI_i \cdot \frac{VA_i}{VA_{TOT}} \right\} - \sum_i \left\{ av(RI_i)_G \cdot \frac{VA_i}{VA_{TOT}} \right\} .$$

Now, since $RI_i = \frac{R\&D_i}{VA_i}$ , where $R\&D_i$ is the R&D expenditures of industry *i*, we have

$$STI_{diff} = \sum_i \left\{ \frac{R\&D_i}{VA_i} \cdot \frac{VA_i}{VA_{TOT}} \right\} - \sum_i \left\{ av(RI_i)_G \cdot \frac{VA_i}{VA_{TOT}} \right\}$$

and

$$STI_{diff} = \sum_i \frac{R\&D_i}{VA_{TOT}} - \sum_i \left\{ av(RI_i)_G \cdot \frac{VA_i}{VA_{TOT}} \right\} .$$

Since the sum of R&D expenditures in each industry over all industries obviously equals total R&D expenditures in all industries taken together, this gives

$$STI_{diff} = \frac{R\&D_{TOT}}{VA_{TOT}} - \sum_i \left\{ av(RI_i)_G \cdot \frac{VA_i}{VA_{TOT}} \right\} ,$$

where $R\&D_{TOT}$ is total R&D expenditures in all industries taken together. Now, $\frac{R\&D_{TOT}}{VA_{TOT}}$ is nothing but the R&D intensity of the total economy or sector we are dealing with, which in this case means the manufacturing sector as a whole. We will denote the R&D intensity of the total by $RI_{TOT}$ . We may thus write the indicator based on percentage differences as

$$STI_{diff} = RI_{TOT} - \sum_i \left\{ av(RI_i)_G \cdot \frac{VA_i}{VA_{TOT}} \right\} .$$

This expression allows us fairly clearly to see what determines the magnitude of the indicator based on percentage differences. The indicator depends, in the first place, on the total manufacturing R&D intensity of the country, which is our point of departure. This is then modified by the subtraction of a magnitude which is an expression of the industrial structure of the country in question. This structure expression, $\sum_i \left\{ av(RI_i)_G \cdot \frac{VA_i}{VA_{TOT}} \right\}$ , which is the manufacturing R&D intensity the country would have had *if*, *given* the industrial structure that it actually has (the set of $\frac{VA_i}{VA_{TOT}}$ 's), it in each industry had an R&D intensity equal to the average R&D intensity in the industry across the group of countries entering the comparison. Thus we see again, but from a different angle, that if a country in each individual industry has an R&D intensity equal to the industry average R&D intensity across the group of countries, the indicator will take the value 0. If a country has an industrial structure characterized by a relatively large share of manufacturing production in the industries which on average have a high R&D intensity, the expression $\sum_i \left\{ av(RI_i)_G \cdot \frac{VA_i}{VA_{TOT}} \right\}$ will be relatively high, which means that the country in question will have to have a relatively high total manufacturing R&D intensity to get an indicator value above zero. Conversely, if a country has an industrial structure characterized by a relatively high share of manufacturing production in the *low* R&D intensity industries, the expression $\sum_i \left\{ av(RI_i)_G \cdot \frac{VA_i}{VA_{TOT}} \right\}$ will be relatively *low*, which means that it will suffice with a relatively *low* overall manufacturing R&D intensity for the country in question to get a positive indicator value.

Thus, the indicator based on percentage differences, as witnessed by the expression

$$STI_{diff} = RI_{TOT} - \sum_i \left\{ av(RI_i)_G \cdot \frac{VA_i}{VA_{TOT}} \right\} ,$$

equals the actual total manufacturing R&D intensity of the country in question *minus* a term which expresses the industrial structure of the country. Now, rearranging this expression we get

$$RI_{TOT} = \sum_i \left\{ av(RI_i)_G \cdot \frac{VA_i}{VA_{TOT}} \right\} + STI_{diff} ,$$

and substituting the first expression we gave of the percentage difference indicator above, we get

$$RI_{TOT} = \sum_i \left\{ av(RI_i)_G \cdot \frac{VA_i}{VA_{TOT}} \right\} + \sum_i \left\{ \left( RI_i - av(RI_i)_G \right) \cdot \frac{VA_i}{VA_{TOT}} \right\} .$$

With this last expression, we see that we get a *decomposition* of the total manufacturing R&D intensity of a given country, where the total manufacturing R&D intensity of the country can be expressed as the sum of two different components. The first component, $\sum_i \left\{ av(RI_i)_G \cdot \frac{VA_i}{VA_{TOT}} \right\}$, is an expression of the industrial structure of the country, reflecting the share of , respectively, high R&D intensity and low R&D intensity industries in total manufacturing production. The second component, $\sum_i \left\{ \left( RI_i - av(RI_i)_G \right) \cdot \frac{VA_i}{VA_{TOT}} \right\}$, is an expression of how well the country on (weighted) average performs compared to other countries in terms of R&D intensity inside each individual industry.

Let us give an example of an empirical application of this decomposition.[4] Using data on R&D expenditures and value added in 22 manufacturing industries for the year 1985 in 12 countries (USA, Japan, West Germany, France, Great Britain, Italy, Canada, Australia, Denmark, Finland, Norway and Sweden), we found a relatively high positive correlation of r = 0.67 between absolute size of economy, as measured by GDP, and R&D intensity in the manufacturing sector. However, the correlation between GDP and the industrial structure component of the above decomposition was higher than this, with r = 0.74, whereas the correlation between GDP and the R&D intensity within the individual industries component was lower, with r = 0.48. And when we instead of GDP used *Ln GDP* as a measure of size of economy, we found an even larger difference between the two components. The correlation

[4] See Tore Sandven and Keith Smith, ‘R&D and Industrial Structure in a Comparative Context”, *Fremtek-notat* 5/93, NTNF Programme Future-Oriented Technology Policy, Oslo 1993.

between Ln GDP and total manufacturing R&D intensity was moderately high, with $r = 0.53$, whereas the correlation between Ln GDP and the industrial structure component was very high, with $r = 0.88$ and the correlation between Ln GDP and the R&D intensity within the individual industries component was very low, with $r = 0.19$. This seems to indicate that the difference between large and small economies in terms of manufacturing R&D intensities is more a reflection of differences *in industrial structure* between large and small economies than of differences in R&D performance given the industrial structure that the respective economies actually have.

We have said that the indicator based on percentage differences measures how well the country in question *on average* performs in terms of R&D intensity within the individual industries. As is plain from the expression $STI_{diff} = RI_{TOT} - \sum_i \left\{ av(RI_i)_G \cdot \frac{VA_i}{VA_{TOT}} \right\}$, the value of this indicator does *not* depend on the distribution of R&D resources across industries. The only place in the expression where the R&D expenditures of the country in question enter, is where total R&D expenditures are divided to total value added. Apart from this, the indicator only depends on the industrial structure of the country. This seems quite reasonable as long as we want to adjust for *industrial structure*. But as with all averages, this too may, on the one hand, be an average of reasonably equal figures, or, on the other hand, of a highly unequal distribution. In the latter case, of course, the average will not tell us much and may even be highly misleading. Thus, if we want to say something about the *distribution* of R&D resources across industries, we must add other measures and descriptions.

# Conclusion

The indicator of R&D intensity adjusted for industrial structure based on percentage differences,

$$STI_{diff} = \sum_i \left\{ \left( RI_i - av(RI_i)_G \right) \cdot \frac{VA_i}{VA_{TOT}} \right\} ,$$

we saw could be written as

$$STI_{diff} = RI_{TOT} - \sum_i \left\{ av(RI_i)_G \cdot \frac{VA_i}{VA_{TOT}} \right\} .$$

This indicator adjusts for industrial structure, but says nothing about the distribution of R&D expenditures across industries. This is easily seen from the last expression. If we hold total manufacturing R&D intensity constant and vary the distribution of R&D expenditures across industries, we see that this does not affect the value of the indicator whatsoever. On the other hand, still holding total manufacturing R&D intensity constant, if we vary the industrial structure, the indicator value will change accordingly, and in a quite reasonable and logical way. A country with a comparatively large share of its production in low R&D intensity industries may still have a high R&D intensity indicator value even though the R&D intensity of the manufacturing sector as a whole is comparatively low. Most likely this will come about because the country quite generally has an above average R&D performance in each individual industry. But it is, of course, also possible that it gets a high indicator value because it has an R&D intensity far above average in a couple of industries accounting for a rather small share of total production while performing below average in the majority of industries accounting for the bulk of total production.

The OECD STIBERD or STIRD indicator,

$$STIRD = \sum_i \left\{ \frac{RI_i}{av(RI_i)_G} \cdot \frac{VA_i}{VA_{TOT}} \right\} ,$$

can, as we have shown above, be written as

$$STIRD = \frac{1}{VA_{TOT}} \cdot \sum_i \frac{R\&D_i}{av(RI_i)_G} .$$

As we have shown above, the STIBERD or STIRD indicator does *not* depend on the industrial structure of the country in question. If we again hold total manufacturing R&D intensity constant, i.e. if we hold total R&D expenditures divided by total value added constant, and vary the industrial structure, the indicator value is not affected whatsoever. On the other hand, the STIRD indicator does depend on the *distribution* of R&D expenditures across industries, as is again easily seen from the last expression above. Again holding total manufacturing R&D intensity constant, if we vary the distribution of R&D expenditures across industries, the indicator will vary accordingly.

However, as we have seen, the STIRD indicator adjusts for the distribution of R&D expenditures across industries in a distorted way. Given total manufacturing R&D intensity, the more these expenditures are concentrated in the industries which have the lowest R&D intensities on average across the group of countries, the higher the STIRD value gets, and it reaches its maximum when all R&D resources are concentrated in the industry with the lowest average R&D intensity across the group of countries.

Imagine that the STIRD indicator was to be used as a guide for R&D policy. Extra resources of a considerable amount have been granted to support industrial R&D, and the question is how these extra R&D resources should be allocated across industries. Using the STIRD indicator as a guidance, the answer would be that all of them should be allocated to the industry with the lowest average R&D intensity across the group of countries. And this will be the case irrespective of how large or small share of manufacturing production this industry represents, and irrespective of how much R&D resources the country in question already has allocated to this industry. (Of course, if the number of countries in the group is small and one of them allocates atypically much R&D resources to this industry, the average R&D intensity of the industry will rise and eventually it will no longer be the industry with the lowest average R&D intensity. But this eventuality does not affect the general argument put forward here.) This seems as bit perverse.

Now, in practice, things are not quite as bad as the above theoretical analysis suggests, because there tends to be a negative correlation, although far from perfect, between R&D intensity and share in industrial production at industry level, and generally the low and medium R&D intensity industries together account for a larger share of manufacturing production than the high R&D intensity industries. But on the other hand, in countries like USA, Japan and Germany the medium and high R&D intensity industries together account for a significantly larger share of manufacturing production than the low R&D industries. There is thus ample scope for serious distortion from the application of the STIRD indicator. And: the policy implications of the STIRD indicator will be *the same irrespective of the industrial structure of the country in question*. Whether the low R&D intensity industries account for a relatively large (as in Finland, Denmark, Australia) or a relatively small (as in USA, Japan, Germany) share of manufacturing production, the policy implications of the STIRD indicator would still be that as much R&D resources as possible should be allocated to the industries with the lowest average R&D intensities in the international comparison.

There is a general problem with the presentation of the STIRD or STIBERD indicator in the OECD documents, for instance the STAN indicator note, namely that the question of adjusting for industrial structure is not clearly distinguished from the question of taking account of the allocation of R&D resources across industries. Instead the STAN indicator note talks rather indiscriminately of adjusting for industrial structure *and* of measuring the allocation of R&D expenditure across different industries (cf. for instance the STAN indicator note, p. 2), as if the single

STIRD indicator value somehow expresses both dimensions. But this will only be so in the rather unproblematic and rather unrealistic case of no ‘statistical interaction’, so to speak, i.e. where the relative R&D intensity performance of the country is roughly the same in all industries, for instance, where it is about average in all industries, or where it is an ‘equal distance’ above or below average in all industries. But in the empirically relevant case of more or less pronounced ‘statistical interaction’, where, for instance, the R&D intensity performance of the country in question is approximately average in some industries, above average in some industries, below average in others, *far* below average in some, etc., the two questions should not be confused.

In conclusion, the OECD STIRD or STIBERD indicator has serious shortcomings as an R&D performance indicator ‘that explicitly takes account of the different industrial structures of different countries’ (STAN indicator note, title page). We have seen that it does *not* in any meaningful sense adjust for differences in industrial structures across countries. What it *does* reflect is differences in the allocation of R&D resources across industries, but only, as we have seen, in a rather distorted way.

As we have seen, the alternative structural indicator presented above, based on percentage *differences* instead of the quotients which form the basis of the STIRD indicator, adjusts for industrial structure in a quite reasonable and logical manner. A better solution would then be to use this indicator to adjust for industrial structure. However, this indicator says nothing about the distribution of R&D expenditures across different industries. To take account of this distribution aspect, we would have to supplement the indicator based on percentage differences with other descriptions and measures. If we aim to express this distribution by means of a single indicator, this should be constructed so that, given the total manufacturing R&D expenditures of a country, it reaches its maximum value when there is a *reasonable* distribution of R&D resources across different industries, not, as is the case with the STIRD indicator, when this distribution is extreme and highly irrational.

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STEP-gruppen ble etablert i 1991 for å forsyne beslutningstakere med forskning knyttet til alle sider ved innovasjon og teknologisk endring, med særlig vekt på forholdet mellom innovasjon, økonomisk vekst og de samfunnsmessige omgivelser. Basis for gruppens arbeid er erkjennelsen av at utviklingen innen vitenskap og teknologi er fundamental for økonomisk vekst. Det gjenstår likevel mange uløste problemer omkring hvordan prosessen med vitenskapelig og teknologisk endring forløper, og hvordan denne prosessen får samfunnsmessige og økonomiske konsekvenser. Forståelse av denne prosessen er av stor betydning for utformingen og iverksettelsen av forsknings-, teknologi- og innovasjonspolitikken. Forskningen i STEP-gruppen er derfor sentrert omkring historiske, økonomiske, sosiologiske og organisatoriske spørsmål som er relevante for de brede feltene innovasjonspolitikk og økonomisk vekst.

The STEP-group was established in 1991 to support policy-makers with research on all aspects of innovation and technological change, with particular emphasis on the relationships between innovation, economic growth and the social context. The basis of the group's work is the recognition that science, technology and innovation are fundamental to economic growth; yet there remain many unresolved problems about how the processes of scientific and technological change actually occur, and about how they have social and economic impacts. Resolving such problems is central to the formation and implementation of science, technology and innovation policy. The research of the STEP group centres on historical, economic, social and organisational issues relevant for broad fields of innovation policy and economic growth.