Indicators for Measuring the Global Performance and Value of Innovations*

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A set of indicators to measure several aspects of the global performance and value of technological innovation at the technical, economic and strategic levels are proposed. Whereas the definition and measurement of technical and economic aspects of global performance at company sphere seem to be relatively easy, the definition and measurement of “value” are more difficult, because value today cannot simply be related to the economic results of processes and products at the company level, but it must be also referred to the macroeconomic and social spheres. Nonetheless, this proposal is intended to cover the main aspects of “internal” performance and “external” impacts, together with providing an analysis of the reliability and origins of the data that are needed in order to elaborate the indicators, with particular emphasis being placed on those indicators for the measurement of the socio-economic and strategic value/advantage of new technologies. Within the company sphere, the proposed indicators can measure the materials, energy, environmental, operational, volume, inputs effectiveness/efficiency of a process, and the quality and environmental performance of a product, both at the technical and economic level. Within the socio-economic sphere, they can measure the effects produced by a partially or radically new technology on total and intellectual employment, and on the environment. Within the strategic sphere, they can measure domestic and international importance, the degree of indispensability, and the knowledge advancement. These indicators have been applied to some real cases; the single figures (0-100) can be summed up to give a final index (0-3000) which can be used to compare two different situations involving the same producer (before and after a technological modification), or involving different producers operating either in the same economic field or in different fields. Data at company sphere can be easily elaborated from the specific information system, while those at macro-sphere are more difficult to be found and an effort needs to be made by statistical Agencies in order to arrive at analytical and reliable figures. Moreover, at the company sphere, data can be drawn 6 to 12 months after the innovation has been implemented, while at the macro-sphere it is advisable to wait for 1 to 2 y.

The Dimensions of the Global Performance and Value of Innovations

As a consequence of the increasingly important role that complex, advanced and sophisticated production technologies are playing in satisfying the needs of producers, consumers and society as a whole, there is a real need for a set of parameters with which to accurately measure the “internal” performance (company sphere) of new technologies, both from a technical and an economic viewpoint, and their “external” advantage (within the socio-economic and strategic spheres), which include the various effects prompted by innovations. These effects are deemed necessary in order that potential global advantage and results may be quantitatively assessed, so that companies, managers, investors, policy makers and public authorities can all gather the data they need in order to arrive at the right decisions in any particular situation.

A new term, “technometrics”, has been coined to indicate the science that measures the technical performance of technologies. Grupp has recently made an important contribution to the schematization of the various algorithms used in measuring the technical characteristics of innovations, making use of the following scientific-orientations: insignificance of time axis, coupled with production differentiation, without product variants, and historical contingencies. Technical performance has usually been assessed through the measurement of process productivity and product quality, economic performance is mostly measured by means of return on investment indices.

We do not want to discuss here the complex subject of value which has been studied by several economists primarily from a theoretical point of view. We only want to recall the different routes that have been followed, in order to set the reasons why value must be regarded in a new and wider perspective. The first route is based on the objective theory of value that takes into consideration the cost-of-production and labour theory; and the other method to accommodate value is the subjective route of marginal utility theory. In the former, which is close to the Marxist labour...
theory of value it is presumed that all goods and services represent "congealed labour" and the comparison of "embodied labour" indicate the trade-offs between production alternatives. This led to a distance between this theory considering labour the basis for value, and neo-Ricardians, who consider relative costs of production the fundamental standard of valuation. In the neo-Ricardian perspective the relative cost of production of any good can be transformed into direct and indirect input requirements, for instance primary energy. By focusing on the energy used in production processes, these authors do not construct a new theory of value, but rather a number of energy indicators which can contribute to natural resource and environmental management, and to the decision making process in technological choices. Some analysts sought to use thermodynamic measures (entropy) to evaluate environmental impacts. This aspect of environmental impact is becoming more and more important in all economic activities and transformation.

Attempts to substitute monetary valuation by an entropic measure or a measure of energy — the latter as a standard of value, reveal a conceptual limitation about nature of value itself. It is necessary to draw the distinction between energy as unit of value and the use of an energy unit as a suitable unit of measure for a production-cost theory of value. Podolinski was the first to attempt to combine the concept of labour as source and measurement of value with that of energy, since the production of goods needs both of them and since energy can replace labour through machines; a discussion on this combination has been recently made by Martinez-Alier, whereas Odum has suggested the assessment of goods and services in terms of embodied solar energy content (by using transformation ratios). This valuation technique can be used to define indicators and also to assess the role of ecological parameters in economic processes. Therefore, if elaborations are carefully conducted, results can be rendered useful in comparing different products and processes. This same can furnish reliable information about the opportunity costs. Of course, the value assessment, made only through the embodied energy, as at present, is not sufficient for drawing an overall assessment.

From a practical point of view, we are used to considering value either as the commercial economic level (price) at which specific equipment or products can be bought, or the potential economic value that can be ascribed to them according to their "capacity to furnish economic results". The former definition is an absolute, indubitable one, but it completely ignores economic performance and results, which are in fact of prime importance in every economic situation; the latter definition, on the other hand, does relate value to performance/results, although these can vary considerably according to the prevailing conditions (both operative and external). In this sense, we must recall the more general ideas of cost-effectiveness and cost-benefits.

All this limitations of the various theories suggest a redefinition of value especially when one wants to assess the effects related to technological innovations, which, at this sphere, mean validity/effectiveness/advantage obtainable from an innovation, to be measured in respect of a number of different, albeit closely interrelated, parameters of technical, microeconomic, macroeconomic (social), and strategic variety. In other words, "value" should be regarded in a "tetradic dimension", leading to generation and capture of objective data capable of representing "the results that production technologies and products provide at the internal (company) and external (overall economic sphere) levels".

This articulated proposal constitutes a further development on previous ideas. Figure 1 provides a scheme of the multiple dimensions of the performance/advantage/value of new technologies. It is clear that the various proposed parameters — and the corresponding figures — are closely related together, and each one contributes to the final (global) value. As it is underlined below, the parameters at company level are measurable with a high precision, some of those at macro-level are measurable with lower precision especially because of the difficulty at the international and national level to generate and capture analytical and timely data concerning all effects of the introduction and diffusion of innovations.

The Nature of Indicators

Micro-sphere (Company) — There are several factors, both traditional and non-traditional, which permit us to quantitatively assess the global performance (effectiveness/efficiency) of processes and technologies, and this assessment should be taken as the basis for the measurement of the technical and economic performance of the technology. We should point out here that it is easier to identify and measure the various factors that contribute to the global performance of a process rather than of a product, particularly since products have some properties which are either subjective (non-measurable) or representative of functions.
whose method of measurement has still to be clearly defined.

**Technologies** — In previous research work, certain intrinsic operative properties of processes had been identified and proposed for the global assessment of the performance of such processes [42,47,20], those here proposed are an evolution of them, together with some new ones. They can be used to measure such fundamental features and results as: materials and energy efficiency, environmental efficiency, process flexibility and versatility, and process functionality. The information resulting from working out the proposed ratios, constructed on the above mentioned data can be used either separately, for specific purposes, or jointly, in order to obtain intermediate indices within a relevance tree that considers them in couples, as two interrelated facets of a single indicator [42,43]. This then gives a final index (0 to 100); or, alternatively, the single figures obtained, since they are expressed as percentages (0 to 100 per cent for each factor), can be added. The second option is easier to work out, and has thus been chosen here. Of course in both the cases, the lowest figure, 0, as well as the highest figures, 100 and 800, are only theoretical; as a matter of fact, we are unlikely to come across a situation where a ratio is equal to 0 (or very close to zero) or to 100 (materials and energy efficiency ratios, or environmental efficiency ratios, for example). The ratios are structured and normalized in such a way as to provide relative data of a comparable nature, and consequently they come within the 0 to 100 range, although the extremes of 0 and 100 are very rarely obtained. Given this, it would be more realistic to set a range of between 30 to 40 and 80 to 90. Nonetheless, the most valid range is the theoretically possible one, i.e. 0 to 100.

Figure 2 shows the structure of the indices relating to the measurement of the eight different aspects of the technical performance of technologies. It should be clear that, whereas the eight selected parameters (ratios) represent the main facets of the global performance of processes, they can be considered at the same time individually. This can be done in order to identify the nature of the results achieved after an innovation, its weak and strong points, and the parameters jointly can be used to assess its global performance. Otherwise, their close reciprocal relationships are well known, and they can also be visually observed in Figure 1 by following the logical progression of the sub-indices at the first level of synthesis (materials and environmental valorization, process versatility/flexibility, and process efficiency) and at the second level (resources valorization and process functionality). This method of approaching this complex subject can be followed also for all the subsequent parameters reported in Figures 2-7, because this one provides the rationale for the proposed elaboration. Economic performance of processes/technologies are a direct consequence of technical performance and the correspondence between the two can be seen in Figure 2. For both technical and economic performance of technologies, reliable data can be easily taken from company accountancy and information system. The above considerations, concerning the range of data between 0 and 100, are once again valid here.

**Products** — We may point out here that the specific features of products have multiplied over the past 20y, as a result of new needs arising from the new industrial and economic revolution which began at the beginning of the ’80s (i.e. the need for demand diversification, for environmentally-friendly products, for global competitiveness, etc.). New functional properties have been added to the traditional qualitative properties of some products, and we can expect new ones to be introduced (serviceability, transportability, ease of storage and conservation, therapeutic effect, detergent effect, anti-parasitic effect, fertilising effect, safety, etc.). All these changes are needed in order to pursue the goals of maximizing results for the various users, and minimizing costs throughout the entire life-span of goods. We must point out here that some of the new functional properties are measurable, whereas
Figure 2 — Indicators for the measurement of the various aspects of the technical performance of different technologies
- Added value of raw materials (Percentage increase after processing of the raw materials cost) (0-100)
- Added value of energy (Percentage increase after processing of energy cost) (0-100)
- Process Environmental Efficiency
  Value of the materials actually included
  (total cost of materials × conversion rate) - Total cost of reducing the products’ dissipation potential
  of the original and intermediate materials and
  compounds (potentially polluting) used in the
  process and not transformed into products
  Value of the materials actually included in the products
  (total cost of materials × conversion rate) (0-100)
  (Sum of the individual values for the various materials and products)
- Energy Cycle Environmental Efficiency
  Value of the energy actually utilized in the process
  (total costs for energy × conversion rate) - Total cost of minimizing the dissipation potential
  of polluting emissions in the energy cycle
  Value of the energy actually utilized in the process
  (total cost of energy × conversion rate) (0-100)
  (Sum of the individual values)
- Equipment Static Operating Efficiency
  Amortization share in the average unit production cost for the consolidated product mix
  Additional amortization share due to breaks for setting-up and
  production cost for the consolidated product mix
  Amortization share in the average unit production cost for the consolidated product mix
  (0-100)
- Equipment Dynamic Operating Efficiency
  Amortization share in the average unit production cost for the consolidated product mix
  Additional amortization share due to breaks for setting-up and
  production cost for the new product mix
  Amortization share in the average unit production cost for the consolidated product mix
  (0-100)
- Product Volume Efficiency
  Actual value of sold products
  Maximum value of obtainable products
  (0-100)
- Input Efficiency
  Optimal unit production cost
  Actual unit production cost
  (0-100)

Possible score 0-800

Figure 3 — Indicators for the measurement of the various aspects of the economic performance of technologies.
some are not measurable as yet. In order to formulate a global performance index which may be of use in assessing the "global value" of a product, we first need to identify the properties/functions that are measurable and that are seen to contribute towards quality configuration. They can then be combined, two by two, using a simple formula, so as to give a final index, or they can be simply summed together. Of course, theoretical maximum and minimum values have to be set beforehand, in both the cases.

For instance, in the case of automobiles, the traditional range of properties such as acceleration, fuel consumption and speed, must now be widened with the inclusion of properties/functions such as: time for the substitution of the major mechanical and body parts, crash resistance, breaking distance, amount of emissions, noise level. For computers: clock frequency, cache memory, cache memory expandability, available slots, available internal casing, CD Rom speed, hard disk memory and Ram memory are the main performances. Of course, for all goods and services the specific properties/performance characterizing their global performance have to be selected and the possible variation range identified. Reliable and timely data can be taken from market and company provided information, especially in case we want to provide high transparency and attention toward consumer. In the case of foodstuffs: the content of proteins, carbohydrates and fats, is bolstered by the inclusion of other functions such as their ease of conservation, and the degree to which they are healthy. In the case of detergents, their degree of whiteness, their biodegradability, their solubility and detergent effect are all to be taken into consideration (and all of them are measurable with high precision).

In conclusion, we can say that the first phase consists in identifying properties/functions that are of importance while defining "global quality" and these properties, etc. constitute the basis for the optimal use of that product. Of course, all quality factors must be quantifiable. The important example of automobiles is given below (Figure 4). The main properties/performances have been taken into consideration, although other parameters may be used.

The final index, obtained by combining the operative functionality and reliability indices, represents the level of absolute quality, and the range extends from 1 to 100 (even if the lowest figures are no lower than 30 and no higher than 80).

Instead of combining the eight parameters in twos, it is easier to sum single figures after having normalized them between 0 and 100: in this way, the final index will range from between 0 to 800. However, something that is of equal importance for the assess-
Degree of product quality diversification

Higher Global Performance - Lower Global Performance

Mean for the performance index of the product mix (0-100)

Product Quality Stability

Maximum observed interval for the performance indices, over time

Absolute sequential mean difference

\[ \frac{\sum (\Delta \times d \times t)}{n - 1} \]

Maximum observed interval for the performance indices, over time

(Weighted mean of the single values for the various products, measured using the sum total of products or a statistical sample)

Product Environmental Efficiency

Quantities of non-depletable materials present in the products released into the environment (natural and human metabolism) (tons)

Total quantities of materials present in the products (tons) (0-100)

(Addition of the single values for the various products)

Product Environmental Efficiency (0-100) during its utilization

(Elaborated as for the Global Performance indices by using the relevant polluting factors)

Possible score 0-400

Figure 5 — Scheme of the four parameters that contribute towards the formulation of the Global Technical Performance of the products
• **Product Quality Diversification Efficiency**

<table>
<thead>
<tr>
<th>Unit price (or cost) obtained for the most valuable product</th>
<th>Unit price (or cost) obtained for the least valuable product</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corresponding highest performance index</td>
<td>Corresponding lowest performance index</td>
</tr>
<tr>
<td>Weighted mean for the price (or cost) ratio obtained/performance index of the product mix (0-100)</td>
<td>product value</td>
</tr>
</tbody>
</table>

• **Product Quality Stability**

Overall increased commercial value of the products with high stability of quality properties (obtained by increasing the sale price and/or the quantity of the products to be sold) / Total cost of maintaining the highest stability of quality properies (obtained by increasing the sale price and/or the quantity of the products to be sold) (0-100)

• **Product Environmental Efficiency**

Value of the non-depletable materials (or those subject to metabolism) / Value of the materials actually included for the various products (total cost of materials x conversion rate) (0-100)

• **Product Environmental Efficiency during its utilization**

Overall running costs during the utilization of the product / Environmental costs during the utilization of the product (0-100)

Figure 6 — Scheme of the four parameters that contribute towards the formulation of the Global Economic Value of the Products

• Contribution provided to overall employment (percentage variation in overall employment from the previous technology to the new one) over a year period (0-100)

• Contribution provided to intellectual employment (percentage variation from the previous technology to the new one) over a year period (0-100)

• Direct environmental improvement

Investment and running costs to maintain environmental balance / Value of the products obtained, over a one-year period (0-100)

• Induced contribution to the development of cleaner technologies

Induced level of investment for new, cleaner environmental technologies / Induced level of investment for previous technologies, over a one-year period (0-100)

Possible score 0-400

Figure 7 — Scheme of the four parameters used in evaluating the socio-economic value (advantage) of a new technology
• Contribution (direct or indirect) to the technology balance, over a year period
(Annual percentage variation in the technology balance in the same field of activity) (0-100)

• Incidence of the products value in the international market, over a year period
(Percentage variation of the international market share of the economic value of the new products) (0-100)

• Direct domestic economic importance, over a year period
(Annual percentage variation in the economic value of the technology and products in question, in the same field of activity) (0-100)

• Induced domestic economic importance, over a year period
(Annual percentage variation in the economic value of induced and correlated technologies and products in all branches of activity) (0-100)

• Intensity of technological renewal
(The degree of change in the technology in question is obtained by a score relating to the top five features: diversity of the adopted technologies [0-20], lay-out of the processes [0-20], processing time [0-20], productivity [0-20], product mix [0-20]) (0-100)

• Percentage variation of the incidence of non-material inputs in the whole process, referred to their cost on the total production cost (0-100)

• Impact of the new technology on the productive system, over a year period
(Degree to which the new technology can be replaced within the productive system, measured as the percentage variation in the overall economic value of the new products throughout the whole system after the introduction of the new technology) (0-100)

• Pervasiveness throughout the entire productive system, over a year period

\[
\frac{\text{Annual investment in all branches by adopting the technology in question}}{\text{Annual investment in all branches by adopting the technology in question}} \times \frac{\text{Annual investment in the branch of origin by adopting the technology in question}}{(0-100)}
\]

Possible score 0-800

Figure 8 — Scheme of the eight parameters used in the evaluation of the strategic value (advantage) of a new technology

The products’ environmental features are also of fundamental importance. These can be measured in terms of the types of material employed and of the use the products are put to, and these factors can be measured using the ratios given below. The economic performance of products is related both to cost-price/quality properties and to their environmental impact. This can be measured by means of the ratios given in Figure 6. The figures may even...
gies are also an "economic engine", or "fly-wheel" to a sort of "nodality" and they affect, more or less, the whole economic structure. Thus, such technologies have to be considered as "strategic" when they are central to an economy and, for their general macro-economic sphere (Figure 1), this dimension becomes a strong linkage with the strategic value.

**Strategic Sphere** — A further widening of our view of innovation leads us to the concept of "strategic value". This, however, is not an economic concept in the strict sense of the word, but it involves some ideas concerning "bearing" (or leading), as has been pointed out in a previous work. A production activity and its basic technologies have to be considered as "strategic" when they are central to an economy and, for their complex relationships with other activities, give rise to a sort of "nodality" and they affect, more or less, the whole economic structure. Thus, such technologies are also an "economic engine", or "fly-wheel" for a wide number of economic activities. For instance, micro-electronics, optical and information technologies are highly strategic to all economic systems. The same applies to automotive and food technologies. On the contrary, the leather, furniture and cloths technologies are much less strategic.

We must note here that the condition, conducive to the making of a strategy and the degree of strategic-content in an economic activity vary along space and time. Those aspects which are to be taken into consideration and jointly measured (or estimated) while estimating for both technologies and products the degree of its strategic-content, are given in Figure 8. Their possible range of variation is also shown in here. In particular, indicators used to measure ease of interruption, contribution to technology balance, induced domestic importance, innovation, non-material input intensity and pervasiveness, even when not totally accurate, seem to contribute to the evaluation of the strategic degree and the value of a new technology. Some indices may exceed a value of 100 per cent; however, in this case, the data are taken as equivalent to the maximum figure, i.e., to 100. For all of the eight indicators the percentages can also be negative; in this case the data must be subtracted from the total score.

The new index, proposed here for the measurement of the degree and intensity of technological renewal, includes the top features of technologies and products. It is obtained by summing up the scores of the intensity of change in the implemented technologies (which can be measured through the evaluation of the type and performance of various operations), the change in the structure and lay-out of the process, the processing time, the improvement in productivity, and the change in the features of the product mix (a specific study of this question is currently being conducted). It may be pointed out here that the figures for socio-economic and strategic effects, and therefore value, can only be gathered after the new technology has been put into use and its effects have been seen, and only if analytical data are available at the national and international levels.

The time after which the measurement can be made on the strategic effects, is one year after the implementation of renewal if only reliable and analytical data are available by that time, otherwise longer time (two or more years) would be necessary in case such data are not available.

**Concluding Remarks**

The proposal presented here is based on the concept that several dimensions must be considered to achieve a comprehensive view of the complex results/
Table 1 — Data referred to two innovations, taken from the car manufacturing industry

<table>
<thead>
<tr>
<th>Micro-sphere</th>
<th>Case 1: partial innovation in a European automotive industry</th>
<th>Case 2: radical innovation in a Japanese automotive industry</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Technologies</strong></td>
<td>Before innovation</td>
<td>After innovation</td>
</tr>
<tr>
<td>(a) Technical</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Materials cycle efficiency</td>
<td>70</td>
<td>75</td>
</tr>
<tr>
<td>Energy cycle efficiency</td>
<td>55</td>
<td>55</td>
</tr>
<tr>
<td>Process environmental efficiency</td>
<td>62</td>
<td>64</td>
</tr>
<tr>
<td>Energy cycle environmental efficiency</td>
<td>25</td>
<td>30</td>
</tr>
<tr>
<td>Equipment static operating efficiency</td>
<td>70</td>
<td>73</td>
</tr>
<tr>
<td>Equipment dynamic operating efficiency</td>
<td>75</td>
<td>75</td>
</tr>
<tr>
<td>Equipment efficiency</td>
<td>85</td>
<td>85</td>
</tr>
<tr>
<td>Input efficiency</td>
<td>90</td>
<td>92</td>
</tr>
<tr>
<td>Available score (0-800)</td>
<td>532</td>
<td>549</td>
</tr>
<tr>
<td>(b) Economic</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Materials added value</td>
<td>62</td>
<td>66</td>
</tr>
<tr>
<td>Energy added value</td>
<td>85</td>
<td>87</td>
</tr>
<tr>
<td>Process environmental efficiency</td>
<td>44</td>
<td>50</td>
</tr>
<tr>
<td>Energy cycle environmental efficiency</td>
<td>55</td>
<td>55</td>
</tr>
<tr>
<td>Equipment static operating efficiency</td>
<td>60</td>
<td>64</td>
</tr>
<tr>
<td>Equipment dynamic operating efficiency</td>
<td>56</td>
<td>60</td>
</tr>
<tr>
<td>Equipment efficiency</td>
<td>82</td>
<td>82</td>
</tr>
<tr>
<td>Input efficiency</td>
<td>86</td>
<td>90</td>
</tr>
<tr>
<td>Available score (0-800)</td>
<td>530</td>
<td>554</td>
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<tr>
<td><strong>Products</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a) Technical</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Degree of product quality diversification</td>
<td>37</td>
<td>44</td>
</tr>
<tr>
<td>Product quality constancy</td>
<td>88</td>
<td>92</td>
</tr>
<tr>
<td>Product environmental efficiency</td>
<td>70</td>
<td>76</td>
</tr>
<tr>
<td>Product environmental efficiency during its utilization</td>
<td>58</td>
<td>62</td>
</tr>
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<td>Available score (0-400)</td>
<td>253</td>
<td>274</td>
</tr>
<tr>
<td>(b) Economic</td>
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<tr>
<td>Product quality diversification efficiency</td>
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<td>Product quality constancy</td>
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<td>Product environmental efficiency</td>
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<tr>
<td>Product environmental efficiency during its utilization</td>
<td>54</td>
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<td>Available score (0-400)</td>
<td>228</td>
<td>240</td>
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<td><strong>Macro-sphere</strong></td>
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<td>(a) Socio-Economic Effects</td>
<td></td>
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<td>Impulse given to total employment</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Impulse given to intellectual employment</td>
<td>8</td>
<td>12</td>
</tr>
<tr>
<td>Direct environmental Improvement</td>
<td>25</td>
<td>30</td>
</tr>
<tr>
<td>Induced contribution to the development of Cleaner Technologies</td>
<td>8</td>
<td>18</td>
</tr>
</tbody>
</table>

— Contd
effects produced by implementing a partially or radically new technology. Such effects cannot be limited to the company sphere alone: this is because an innovation can provide great advantage to the innovative firm but disadvantage to the economic system as a whole, involving unemployment levels, environmental balance, related activities, technology balance, etc. The task is ambitious, and the proposed indicators are only an attempt to give a systematic solution to the matter, but others can be proposed and implemented.

Several parameters have been chosen based on the idea that the global “value” of innovations (new technologies and products) is closely related to its capacity to provide both companies and society as a whole with economic results. These various parameters have been chosen to capture the four dimensions that seem to contribute to a quantifiable assessment of global value. These are however, of a rather approximate nature in so-far-as the macro-economic and strategic aspects are concerned, and in so far as these are rendered comparable across situations and time. The elaboration of intermediate and final indices using the proposed methods is both at the single-dimension level and at the level of all four dimensions, or the summing of individual figures, leads to a final figure of between 0 and 100, or of between 0 and 3000. This reflects the overall performance/value of technologies (processes) and products, respectively. Of course, the higher the figure, the higher the performance/value.

Table 1 gives figures for two real cases of total innovation in the international automobile industry, which should give a clear, overall idea of the proposed indicators. The first case refers to an incremental innovation in an European automotive manufacturing industry, the second case to a radical innovation in a Japanese automotive industry (they are not indicated for confidentiality). The adopted method consists in the addition of the figures for the various parameters denoting the technical and economic performance of technologies and products, together with their socio-economic and strategic value; all these figures are expressed as percentages, and they can be summed directly without having to weight for them beforehand. It would be interesting to observe the differences between the figures obtained before and after the introduction of a partially or totally new technology. If one considers the various dimensions and parameters as being of different importance in assessing the global performance and value of innovations, it is possible to give them different weights, on the basis of proven elements.

One major point to be highlighted here is that the indicated dimensions are closely related, i.e., the technical performance cannot be considered separately

Table 1 — Data referred to two innovations, taken from the car manufacturing industry — (Contd)

<table>
<thead>
<tr>
<th>Micro-sphere</th>
<th>Before innovation</th>
<th>After innovation</th>
<th>Before innovation</th>
<th>After innovation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Case 1: partial innovation in a European automotive industry</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Available score (0-400)</td>
<td>44</td>
<td>62</td>
<td>48</td>
<td>67</td>
</tr>
<tr>
<td>(b) Strategic effects</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Contribution to technology balance</td>
<td>6</td>
<td>9</td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td>International market share of the products obtained</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Direct economic importance</td>
<td>14</td>
<td>20</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Induced economic importance</td>
<td>18</td>
<td>28</td>
<td>12</td>
<td>13</td>
</tr>
<tr>
<td>Innovation intensity</td>
<td>30</td>
<td>45</td>
<td>45</td>
<td>60</td>
</tr>
<tr>
<td>Incidence of non-material inputs</td>
<td>25</td>
<td>25</td>
<td>35</td>
<td>42</td>
</tr>
<tr>
<td>Degree of replaceability (interruptibility)</td>
<td>41</td>
<td>50</td>
<td>37</td>
<td>47</td>
</tr>
<tr>
<td>Pervasiveness in the productive system</td>
<td>52</td>
<td>50</td>
<td>44</td>
<td>48</td>
</tr>
<tr>
<td>Available score (0-800)</td>
<td>188</td>
<td>229</td>
<td>199</td>
<td>242</td>
</tr>
<tr>
<td>Total available score (0-3600)</td>
<td>1775</td>
<td>1908</td>
<td>1750</td>
<td>1923</td>
</tr>
</tbody>
</table>
from the economic aspects, and vice-versa; both of them (micro-sphere) affect the socio-economic effects, which, within the macro-sphere, are linked to the strategic effects (they are part of them). This is why the proposed methodology is based on the summing up of the single figures referred to by each parameter. The figures for each parameter can be measured as soon as the results/effects have been realized, \textit{ex ante} at the company dimension (micro-sphere) and \textit{ex post} at the macro-economic dimension.

Since the rate of change in an economy is increasing, it is possible to carry out the measurements, after a year, since the implementation of technological renewal; this is easy at the company level (it is easy also after six months), but it is much more difficult at the macro-level. The proposed method, even while complex, permits evaluating separately the individual aspects of performance/value of new technologies. Moreover, this permits measurement of results and effects. In order to achieve a synthetic global index, even if data for some parameter are approximate and considering the present status of international and national information systems, the errors made during elaboration of different cases could be treated equivalent, and the final evaluation can thus be considered valid and useful.

References

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