In Search of a European Paper Industry Ranking in Terms of Sustainability by Using Binary Goal Programming

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Abstract Sustainability is a multidimensional concept in continuous evolution. However, the suitability of using several indicators of a diverse nature to characterise and quantify this concept has been widely accepted. Within this orientation, in this work, the paper industry's sustainability in a significant number of European countries has been analysed. To achieve this purpose, a set of economic, environmental and social indicators have been defined for the year 2004. With the help of a binary goal programming model, these indicators were aggregated into a synthetic index that measures the overall sustainability of the industry analysed. In this way, a "ranking" according to the sustainability of the paper industry in the European countries studied has been obtained.

1 Introduction

The term "sustainability" is easy to understand intuitively, although it is not at all easy to conceptualise, to measure or to formalize rigorously. Different international forums related to sustainable development have recognized that the term implies ecological and economic dimensions (Diaz-Balteiro and Romero 2008). However, from an entrepreneurial perspective, the concept of sustainability is more questionable. In fact, from a business undertaking point of view, sustainability on many occasions is linked to components related to competitiveness, innovation and the marketing of companies, and with this combination of ideas, a certain company is able to differ from its competitors in order to improve its economic performance. Thus, nowadays, the diverse environmental components of some firms are not only included through several environmental quality systems, but also in their own strategies (Aulí 2002).

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In this paper, we have attempted to characterize the sustainability of the paper industry at a European level, but not by trying to distinguish the firms that show tangible results in some aspects like the "triple bottom", eco-efficiency, or the installation of certain environmental management systems. On the contrary, we have defined a set of indicators that permit the characterization of the managerial reality of these industries under sustainability terms. The proposed approach has been applied to the paper industries of a significant number of European countries. To undertake this task, the methodology used has been based on a goal programming (GP) model with binary variables. This approach has been successfully applied in forestry systems (Diaz-Balteiro and Romero 2004a, b). It should be noted that this type of orientation, defining sustainability by using a set of indicators, appeared in the mid 1980s and was consolidated after the 1992 United Nations Conference on Environment and Development in Río de Janeiro. After that Conference, different lists of sustainability indicators have been proposed for their application, for instance, to different forest contexts (Castañeda 2000). However, the proposed indicators have not been defined at an entrepreneurial level. Consequently, there are few papers explicitly dealing with this topic in the forest industry. One exception to this trend is the work of Hart et al. (2000), in which different cases corresponding to multinational firms were analysed. They mainly focused on qualitative aspects, related to how some of these firms managed their forests. A similar approach can be found in Johnson and Walck (2004), who described five criteria necessary for integrating sustainability into forest industries. The complexity of selecting a representative set of key indicators has already been approached by several authors in their research on sustainability associated with forest management problems (Mendoza and Prabhu 2000a, b).

2 Sustainability Indicators

In order to define the sustainability of an industry or of a group of industries, it is necessary to measure different types of indicators: economic, social, environmental, etc. Nowadays, it is necessary to link sustainability at the entrepreneurship level not only to the existence of the firm as a simple supplier of goods with a market value, but also to another group of attributes (social, environmental) that can provide it with a higher added value as a function of the consumers' perceptions. In the last few years, these intangible attributes have been integrated into expressions like "corporate social responsibility".

Although we have incorporated all these attributes into this study, the industrial nature of the activities considered imposes the prevalence of economic indicators. Also, the scant level of the disaggregation of environment information, which still awaits an adequate treatment, should be underlined. In short, fourteen indicators encompassed in the above perspectives have been selected and are shown in Table 1. In this way, we aimed to include the different aspects of the value chain of the European paper industry which determine a greater or lesser sustainability.

Table 1 Indicators used in this study

	Indicator	Sources	Type
1	Dependence on industrial roundwood	UNECE	More is better
2	Investment rate	Eurostat	More is better
3	Intensity in labour force	Eurostat	More is better
4	Unitary average wage	Eurostat	More is better
5	Gross value added per employee	Eurostat	More is better
6	Energy efficiency	Eurostat	Less is better
7	Innovative enterprises	Eurostat; Statistik Austria	More is better
8	Effects of innovation	Eurostat; Statistik Austria	More is better
9	Acquisition of built-in technology	Eurostat	More is better
10	Patent applications	Eurostat	More is better
11	Gross value added	Eurostat	More is better
12	External competitiveness	UN Comtrade database	More is better
13	Total waste	Eurostat	Less is better
14	Environmental protection expenditure	Eurostat; Statistics Sweden; Czech Statistical Office	More is better

The selection of these indicators was conditioned, firstly, by the information available at a European level. The statistical sources used, such as Eurostat databases, are mainly of an international nature. Similarly, United Nations statistical data of wood products and international trade have been used because the paper industries are integrated into these databases. Nevertheless, when necessary, different National Offices of Statistical data have been consulted.

Next, we have analyzed the meaning of the fourteen indicators selected, which can be classified into two classes or categories: "less is better", or "more is better", since a reduction or an increment in the indicators' values supports the sustainability of the industry. The dependence of industrial roundwood gives valuable information about the different national market strategies for this input, and it is defined by the quotient between imports and apparent consumption. It should be remembered that the latter is equal to the sum of national production plus the imports less the exports.

The investment rate provides information on the intensity in the use of the capital factor for this industry in each country, measured as the quotient between investment and value added at factor cost. On the other hand, the following indicators present, direct or indirectly, labour use as a production factor. Thus, the intensity of the labour force (percentage of labour costs in total production) gives information on the intensity in the use of labour as a production factor for the paper industry in each country. The more traditional sectors, of a lesser complexity and vitality, also use this factor more intensively (Fonfría 2004). For that reason, in this study it was preferable for this indicator to reach its lowest possible value. Conversely, the unitary average wage indicator shows workers' earnings for this industrial sector in each country. Without analysing the differences associated with the national income per capita, a higher value of this indicator is considered as being more sustainable

from a social point of view. Finally, the gross added value per person employed shows an approach to the traditional "average product of labour" concept.

Regarding energy efficiency, this indicator represents a marginal cost, because it covers the amount of energy that it is necessary to buy in order to obtain an additional metric ton of product. Logically, a greater sustainability is reached when the value of this indicator is a low one.

Next, we show four indicators related to innovation. First, the percentage of innovative firms with regard to the total number of firms could be the indicator that shows the penetration rate of innovative activities in the paper industry. Also, the percentage of the total turnover of the paper industry in each country due to innovative firms supplies information about the real importance of those innovative activities in the final outputs of this sector. Actually, the number of patent applications to the European Patent Office in the reference year (2003) is a widely used indicator of the output due to the innovative activities developed in each country, and it has been used in this research. Finally, it has been considered to be appropriate to incorporate the acquisition of built-in technology into this group of indicators, because this is the principal way to incorporate innovation, mainly in small and medium-sized firms. These indicators have been considered as belonging explicitly to the category "more is better", since the higher the figures, the more the paper industry will be sustainable. This is because it is usually recognized that a good way to achieve a greater sustainability of firms could be by increasing the results associated with the I+D+i (Paech 2007).

The gross value added as a percentage with respect to the paper industry in the manufacturing sector constitutes an indicator that shows the relative weight of this industrial sector in the total manufacturing activity of each country. It has been considered that a reduced contribution of value added implies a reduced allocation of resources compared to other more productive and dynamic industrial sectors. In this context, a complementary indicator could be the revealed comparative advantage index (Balassa index). This has been defined as the relationship between the importance of the exports of a certain industrial sector with respect to the total industrial exports in a particular country, and, over a wider area that might be the whole world, Europe, or, in this case, the cluster of European countries analyzed. It represents an external competitiveness indicator, and if this index has a larger value than the unit, a competitive advantage does exist, or, in a contrary sense, it does not.

Finally, in this investigation we included two indicators related to some environmental characteristics of these firms. First, the waste generated by them gives information on the pollutants produced by their industrial activity. To allow a comparison between the different countries, this figure is divided up between the value added corresponding to each specific paper industry. It has been assumed that "less is better", because, in this way, the sustainability of these firms increases. The last indicator in Table 1 shows the quotient between the total current expenses for environmental protection and the number of employees. Here, only the expenditure on environment protection that exclusively affects the period in which it was incurred, without any future economic projection, will be included. For the purpose

of comparing the different figures corresponding to the European countries included in this analysis, this value is distributed between the number of employees. It should be mentioned that, at the moment of carrying out this study, the data corresponding to Italy for the year 2004 was not available, so that, and only for this indicator and country, the year adopted was 2003.

3 Methodology

As specified above, for the purpose of aggregating the different sustainability indicators previously defined into a synthetic index that measures the sustainability of the different countries, an analytic procedure based on GP with binary variables was used (Diaz-Balteiro and Romero 2004b). Thus, we have considered the general case in which there are n countries, evaluating each one of them according to m sustainability indicators, applying the analysis made in the previous section. In this context, a key question was to determine the ranking of the n countries in terms of sustainability.

On these lines, the sustainability indicators were measured in different units, and also with very different absolute values. For that reason, a first stage in our work consisted of appropriately normalising the m indicators. We did so by applying the procedure suggested in Diaz-Balteiro and Romero (2004a, b). The proposed procedure adapted to our context is summed up in the following formulae:

$$\overline{R}_{ij} = 1 - \frac{R_j^* - R_{ij}}{R_j^* - R_{*j}} = \frac{R_{ij} - R_{*j}}{R_j^* - R_{*j}} \quad \forall i, j \tag{1}$$

Where $\overline{R}_{ij}$ is the normalised value reached by the ith country when it is evaluated according to the jth indicator; R_{ij} is the result reached by the ith country when it is evaluated according to the jth indicator; R_j^* is the optimum or ideal value for the jth sustainability indicator. This ideal value represents the maximum value if the indicator is of the "more is better" type, or the minimum value if the indicator is of the "less is better" type. In the same way, R_{*j} is the worst value or anti-ideal value for the jth sustainability indicator.

With this normalisation system, the indicators do not have any dimension and they are all them bounded between 0 and 1. The same procedure was applied in order to normalise the aspiration levels ("targets") of the different indicators. These aspiration levels are exogenous and they are determined by means of expert judgements, as well as from the experience accumulated by the authors. Once this point has been achieved, the following GP model was defined:
Achievement function:

$$Min \quad \sum_{j=1}^{m} \left(\alpha_j n_j + \beta_j p_j\right) \tag{2}$$

Goal and constraints:

$$\sum_{i=1}^{n} \overline{R_{ij}} X_i + n_j - p_j = \overline{t_j} \quad j \in \{1 \ldots m\} \tag{3}$$

$$\sum_{i=1}^{n} X_i = 1$$

$$X_i \in \{0, 1\} \quad i \in \{1, \ldots, n\} \tag{4}$$

$$\mathbf{n} \geq \mathbf{0} \quad \mathbf{p} \geq \mathbf{0}$$

where n_j y p_j are the deviation variables that measure the discrepancies between the value reached by the jth indicator with respect to the aspiration level $\overline{t_j}$. On the other hand, α_j and β_j are the preferential weights associated with both deviation variables. X_i are binary variables that take on the value 1 if the ith country is chosen, otherwise they take on the value 0. By solving the model (2)–(4) the country with the most sustainable paper industry was determined. Applying this procedure in an iterative way, the "ranking" of the countries analysed in sustainable terms was obtained.

In short, the application of the preceding model provides an apparently attractive solution, because it implies the greatest aggregated effectiveness. Nevertheless, this kind of solution can produce highly deviated results for some of the indicators selected, which could be unacceptable when classifying the sustainability for this industry in the countries chosen. To solve this problem, another GP model has been proposed in order to obtain the most balanced solution associated with the achievement of the different goals (Tamiz et al. 1998), with the following analytic expression:
Achievement function

$$Min\ D$$

Goal and constraints:

$$\left(\alpha_j n_j + \beta_j p_j\right) - D \leq 0 \tag{5}$$

where D represents the maximum deviation between an indicator and its aspiration level. However, if we wished to merge both GP models in only one single formulation, then it would be necessary to set up an extended GP (EGP) model, with the following analytic expression (Romero 2004):
Achievement function:

$$Min\ (1 - \lambda)\ D + \lambda \sum_{j=1}^{m} \left(\alpha_j n_j + \beta_j p_j\right) \tag{6}$$

subject to:
Goals and constraints from the model defined by (5).

In this case, for $\lambda = 1$, the most efficient solution, or the one with a better average result has been obtained, while for $\lambda = 0$ the most balanced solution has been elicited. For intermediate values of the control parameter λ, compromises between

both solutions, if they exist, will be obtained. For the resolution of this model, the software LINGO 10 (Lindo Systems 2007) was applied.

4 Results and Conclusions

Once the national values and the normalised aspiration levels for the 14 indicators used in this analysis had been obtained, the EGP model shown in the (6) was applied. Table 2 shows the final ranking of the 17 countries, according to the different values of control parameter λ. In the first place, it can be verified how the ranking associated with the most efficient solution ($\lambda = 1$), is different to the ranking associated with the most balanced solution ($\lambda = 0$). These differences are in some cases remarkable, as can be seen in countries like Romania or the Czech Republic, which notably change their position in the ranking. The country with the most sustainable paper industry was either Portugal or Sweden, according to the different solutions obtained. Conversely, the country with the least sustainable paper industry was Latvia.

It has also been attempted to find out the sensitivity of the solution shown in Table 2, when the preferential weights conferred on some indicators were modified. For this purpose, a sensitivity analysis was developed for four indicators, while the other weights corresponding to the rest of the indicators remained unchanged. The results obtained were different depending on the indicator selected. Thus, whereas changes in the weights associated with the indicator related to expenses for

Table 2 Results according to parameter λ values

$\lambda = 0$	$\lambda = 1$
Portugal	Sweden
Romania	Portugal
Sweden	Finland
The Slovak Republic	Austria
Finland	Germany
Czech Republic	France
United Kingdom	Spain
Hungary	United Kingdom
Lithuania	Estonia
France	The Slovak Republic
Austria	Italy
Spain	Cyprus
Italy	Hungary
Cyprus	Czech Republic
Germany	Lithuania
Estonia	Romania
Latvia	Latvia

environmental protection or to the gross value added per employee did not cause any remarkable changes in the ranking, if a larger weight was given to the indicator measuring the waste generated as a function of the gross value added, the solution was modified irrespective of the value of control parameter λ.

We should like to end this paper by indicating that the procedure followed to obtain an overall measurement of paper industry sustainability in some European countries permits an easy integration of different indicators of a highly diverse nature. Thus, and remembering that, to a certain extent, the selection of those indicators has been conditioned by the data available, it would be necessary to stress that the GP method applied has shown itself to be very flexible, allowing us to obtain the best solution from an aggregated point of view, the best solution from a balanced perspective, or compromises between these two solutions. Finally, this work could be extended in several directions. For example, the models could be replicated by trying to introduce different preferential weights for each indicator considered. These weights could be obtained by means of judgements from experts. Another possible expansion of this research would consist of adapting the analysis at a more disaggregated level, for instance at a managerial one, or analysing in more detail certain industrial subgroups.

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