Determinants of Export Performance: An Analysis using the SOM Algorithm

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Abstract. Mexican international trade growth has been characterized by the relative success of some industries in the US market. In order to analyze determinants of the Mexican export performance, we use a different methodology: the self-organizing map (SOM), which approximates the distribution observed by the economic variables in the original high dimensional space. Consequently, we used the SOM for studying the Mexican exports from 1985 to 2006, at industry level, classified according to their technological intensities. Each year is represented as a vector of 80 components. SOM reflects the similarities and differences in the way exports could be affected by this variables. The results show the efficacy of this approach in explaining the export performance of manufacturing industries. Particularly, the SOM reflects that industries are distributed along the map confirming the existence of notable disparities among them. Moreover, some industries appear relatively near which allow us to suggest these industries, and some of its firms, share important characteristics in terms of export success.

1 Introduction

The self-organizing map (SOM) is a non-linear projection from a multidimensional space to a discrete low-dimensional space. The projection achieved by the SOM is an approximation of the distribution observed by the points in the original high dimensional space [1]. The low dimensional space is a lattice of neurons. Each multidimensional data is mapped to one neuron known as the Best Matching Unit (BMU) for that input data. The set of BMUs from all neurons shows the distribution achieved by the SOM of the multidimensional inputs. Objects located close to each other in the feature space, will be mapped to nearby neurons whereas distant objects will be mapped to distant neurons.

The self-organizing map (SOM) is a model of self-organization of neural connections, which reflects the ability of the algorithm to produce organization from disorder [2]. One of the main properties of the SOM is the ability to preserve in the output map those topographical relations present in the input data [1], a very desirable property for data visualization and clustering. This property is achieved

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through a transformation of an incoming signal pattern of arbitrary dimension into a low-dimensional discrete map (usually one or two-dimensional) and by adaptively transforming data in a topologically ordered fashion [1, 3]. Each input data is mapped to a single neuron in the lattice,to the one with the closest weight vector to the input vector, or BMU. The SOM preserves neighborhood relationships during training through the learning equation, which establishes the effect each BMU has in any other neuron. The weights of the neurons are updated accordingly to:

$$w_n(t+1) = w_n(t) + \alpha_n(t)h_n(g,t)(x_i - w_n(t)) \tag{1}$$

where $\alpha(t)$ is the learning rate at time t, $h_n(g,t)$ is the neighborhood function from BMU, neuron g, to neuron n at time t, and x_i is the inpyt vector. In general, the neighborhood decreases monotonically as a function of the distance between neuron g and neuron n. The SOM tries to preserve relationships in the input data by starting with a large neighborhood and reducing it during the course of training [1].

The paper is organized as follows. The next section explains with more detail the SOM algorithm used to analyze the export performance. Section three presents the results of applying the SOM methodology to some micro and macro variables related to the export performance. Finally, we present the conclusions of this study.

2 Related work and Proposal

SOM has been widely applied as a visualizing tool in different areas. For an introduction and in-perspective analysis of the SOM as a visualizing tool, see [4, 5]. In economics, the SOM has also been a valuable tool for data analysis and forecasting. In the seminal work of Kaski and Kohonen [6], the social welfare of 39 countries is analyzed at the light of 9 variables. Since then, several related works have emerged, and interesting results have been reported [7].

Here, we apply the SOM for studying the Mexican exportations from 1985 to 2006. Each year is featured as a vector of 80 components, where each component corresponds to a given type of exportation (goods or services), Through SOM, we observe similarities and differences in the way this important economic component has been affected.

Mexican international trade growth has been characterized by the export of manufactures of diverse quality and characteristics, and by elevated imports of inputs to be processed and then re-exported. In this way, Mexico has become an important supplier of exports for international markets, in particular for the United States (US).

In this context, the strategy for economic growth has been based, mainly, in the promotion of relatively high intensity technology manufacturing exports. As a result, the weight of exports with respect to the gross domestic product is today near 45%, showing an annual average growth rate of 50%. At the same time, public and private consume spendings and the fixed capital gross investment lost their relevance as sources of economic growth. In the same way, economic growth registered an annual rate of 5% in this period. In consequence, it is accepted that the notable export expansion, given the small rate of change of internal market, is the responsible of that economic growth.

However, manufacturing export industries development has been unbalanced in comparison with the competitive advantages that each one enjoys. The Mexican export specialization is, according to the Organization for Economic Co-operation and Development (OECD) [see www.oecd.org] data, in medium-high and high technology industries, among these are motor vehicles, communication equipment and computing machinery. In contrast, the sectors that reveal the smallest advantages correspond to labor intensive such as textiles, apparel and footwear, which employ capital in a low proportion. But, which factor determines the level of industry exports? Do technology, market structure, foreign demand, costs and other variables affect the success of industries exportation? Do industries share similar characteristic that allow them to export? The answers of these questions have important considerations of industrial policy.

Classification of industries by common characteristics allows a better understanding of the industries behavior and consequently better planning of sectoral politics with the objective of improving, in a coordinated manner, the industrial structure.

On the other hand, foreign trade, owing to new foreign trade theories, can be explained through a multidimensional relationship. Here, the central variables, market structure and technological innovation process, allow domestic industries to reduce average costs as the production level grows, to manufacture new designs and to promote projects that involve research and development with the goal of introducing new differentiated products in international markets. Other aspects like human capital, regional integration and spillover effects derived from foreign technology, play an important role in export performance too.

In this manner, we argue that potential determinants of export performance (or alternatively export competitiveness) of the manufacturing sector in the Mexico-US relationship are gathered in two. In one group, we have the traditional price competitiveness, that includes prices such as real exchange rate or relative unitary cost labor and, on the other, the non-price competitiveness, including innovation processes, domestic production capacity, external demand, scale economies and product differentiation. Likewise, we accept that both kinds of competitiveness affect in different ways each industry.

In this context, based in an abundant set of variables associated with different aspects of the export process, the objective of this paper is twofold. The first is to apply the SOM methodology to the economic analysis and, the second, is to represent the relationships among several potential determinants of foreign trade for each industry, allowing us to group or classify exporting industries considering multiple dimensions. So, by using the SOM algorithm, high-dimensional data can be projected to a lower dimension representation scheme to facilitate the economic analysis.

In this regard, econometric methodology offers several options for estimating the export function, for determining relationships among variables, for simulating politics and for forecasting new relationships. Among econometrics alternatives exist the one equation regression model, the multi-equational models, and time series analysis that have evolved from classic methods to modern techniques that let the researcher determine long run equilibrium relationships. The utilization of this methods in the pursue of our goals implies numerous suppositions, some of them not belonging to the economic theory. For example, it is required to establish some nullity restrictions over the parameters, the type of relationship among variables, sign and nature, and the estimation method, amid others. Simultaneously, these procedures, based on the assumption of linearity, provide us with quantitative arguments regarding the relationships among variables, but they are considerably restrictive and do not necessarily reflect the reality. Hence, modeling with non-linear algorithms seems more appropiate to the actual study.

It is possible to model the export performance through alternative methods like the Self-Organizing Map (SOM). The SOM algorithm, just like econometrics, allows the estimation of relevant relationships between Mexican industries export performance and the variables gathered in price and non-price competitiveness.

Moreover, using the SOM gives additional advantages like the graphic representation in two dimensions of those multivariate relations, which, in turn, allows us to group the international industries in accordance with the common characteristics, from an alternative perspective to the factorial analysis or main components. In other words, through the SOM it can be represented in a map of export performance the state or level of the export success of each industry, recognizing the grade of similarity where potential determinants influence the commercial flows in the industries.

The high number of variables involved in the determination of manufacturing exports make it difficult to analyze and to draw conclusions of interest for the policy makers. With SOM, we expect to greatly simplify the identification of central variables affecting export flows of Mexican industries.

3 Results

The SOM ordered the Mexican exporting industries, as it can be seen in Figures 1a and 1b for the 1985 and 2006 years, respectively. These figures can be interpreted as a map of sectoral export performance although no information of this kind was included in computing and training the SOM. The SOMs show the way industries behave individually as a consequence of different micro and macro economic variables. Several aspects can be inferred from their distribution in the maps. First, in 1985, there is no clear technological pattern of the considered industries; since some low-tech industries, Wood Products and Furniture (20), or medium low-tech, Other Non-metallic Mineral Products (26), are very close to some high-tech industries, Computing Machinery (30) and Pharmaceuticals (2423), in terms of export performance (see table 1 for the complete list of industries).

Table 1. Identification for all industries.

Label	Industry
15-37	Total
15-16	Food products, beverages, and tobacco
17-19	Textiles, textile products, leather, and footwear
20	Wood and products of wood and cork
21-22	Paper, Paper Products, and Printing
23	Coke, refined petroleum products and nuclear fuel
24-2423	Chemicals excluding Pharmaceuticals
2423	Pharmaceuticals
25	Rubber and plastics products
26	Other non-metallic mineral products
27	Basic metals
28	Fabricated metal products, except machinery and equipment
29	Machinery and equipment, n.e.c.
30	Office, accounting, and computing machinery
31	Electrical machinery and apparatus, n.e.c.
32	Radio, television, and communication equipment
33	Medical, precision and optical instruments, watches and clocks
34	Motor vehicles, trailers and semi-trailers
351	Building and repairing of ships and boats
353	Aircraft and spacecraft
352-359	Railroad equipment and transport equipment n.e.c.
36-37	Other Manufacturing

This important result implies that the technological factor is not a main determinant of the export competitiveness of the Mexican firms in that year. That is, despite the differences in innovation capacities among industries (like human capital, import of technology, licenses, or patents) that shape technological advantages in the foreign markets, other variables such as scale economies, market structure, product differentiation, production capacity, foreign investment, labor cost, or external demand influence the performance of these industries in the US market. Moreover, although industries are classified in function of their technological intensities, the Mexican manufacturing industry employed intensively the labor factor even in sectors considered as technologically advanced. Then, we can affirm that differences in the function production, by definition of industry, are counterbalanced by the combination of labor and capital factors in their system of production. Finally, this argument implies a delayed technological competitiveness of the exporting industries. Besides, industries seem to distribute, in general, along the map, implying notable disparities. Distances among industries are relatively large. In particular, low and medium-low technology industries are, in all the cases, considerably separated,by at least two cells; situation we explain with the following arguments. First, the internal capacities of the firms allow them to face the technological opportunities in different ways and with different results. Second, external relations derived from the market led them by diverse growth paths. It can be observed that the SOM algorithm grouped high and medium-high tech industries relatively closer among themselves, as it could be expected due to the technological variables considered in this analysis, which in a way confirms the OECD taxonomy [see www.oecd.org]. Inside the first category, Pharmaceuticals (2423), Computing machinery (30) and Medical and precision and optical instruments (33) keep neighborhood relations; as well as Motor vehicles (34) and Chemicals excluding Pharmaceuticals (24-2423) inside the second group of industries. Following the argument presented above we can assume that technological gaps among these industries are small . This means that industries share similar characteristics in terms of innovation capacities, corporative strategies and are influenced approximately in the same way by the structure market and other variables. Also, the SOM shows how the manufacturing sectors are affected by a set of variables; now we are interested in the individual influence of each variable on each industry. Variations in most of the indicators have not a clearly distinguishable pattern; consequently the distribution of the industries in the SOM reflects this issue. Considering just some fundamental variables, we could assume, for example, that firms market power -oligopolic structure- boost the export performance as new international trade theory proposes(see [8]). Figure 2a reflects how the industries with major exports values are mapped almost together in a column located in the right side of the map. The exporting industries with relative poorer performance in the US market appear in the left side and in the right inferior co rner of the map. Another variable that influences export competitiveness is product differentiation. Figure 2b shows the distribution of the industries in accordance with this indicator. A relatively similar structure emerges from this dimension, that is, we can see a column in the right side of the map; although three industries with high values of product innovation are mapped far of them. As a result, we can state that product differentiation -originated from regular innovation activities- and imperfect market structures are two main determinants of the export performance in a context of high dimensional data inside the US market. On the other hand, external demand and foreign direct investment (FDI) influence the level of exports in the US market in a similar form. The industries are mapped in roughly the same way. Looking at Figures 2c and 2d we can distinguish a cluster of industries located in the bottom part. Also, Figure 2d has another cluster in the right flank, medium-seized. With the values of the exports of the industries included in these clusters, it could be argued that imports and FDI are a second kind of determinants of export performance. Figures 2e and 2f show the cost competitiveness relative unitary labor cost and the production capacity both in the manufacturing sector. The former suggests how cost dimension negatively affects all the industries in terms of their exports except for Other manufacturing (36+37). For example, the export level of Computing machinery (30) was restricted by its low cost advantage derived from the low capital intensity in relation with the intensity in the US market. The latter, although important for some industries, does not appear to be a central factor for the exports; some industries like Coke and refined petroleum products (23), Wood products and furniture (20), Building and repairing of ships and boats (351) and Railroad transport equipment (352+359) move in the same direction of production capacity in the domestic economy. Hence, costs and product capacity are fundamental determinants of the manufacturing exports although the dimension of the map does not seem to reflect the exporting success of all the industries. Finally, we consider the spillover effects -a concept extremely linked with the FDI- over the exporting industries (Figure 2g). This indicator is a source of competitiveness for Fabricated metal products, except Machinery and equipment (28), which means that foreign capital invested in the Mexican economy into this sector has a double impact. First, FDI provides the production and export capacities and simultaneously it gives other kind of advantages such as learning by doing, learning by exporting, technology, etc., that impact in the productivity level of firms in this industry. Nevertheless, once again, the greater effects of these indicators do not occur in the major exporting industries. On the other hand, in 2006, in contrast with 1985, it seems that the industries are mostly grouped in accordance the OECD technological classification. That is, industries with the same technological intensity are relatively close among them (see Figure 1b). Hence, comparing the SOMs, it can be stated that with time a more visible technological pattern of exporting industries emerged. However, there is more dispersion of the sectors and some are mixed with other industries that exhibits different technological capacities. This result implies that in 2006, the technological factor is more important in the export competitiveness of the Mexican firms than it was in 1985. Therefore, although other variables mentioned above -market structure, product differentiation, labor cost, external demand, etc.- influence the success of exporting industries, there are differences in innovation capacities among them that have become the sources of that competitiveness. In other words, the distribution in the SOM suggests that Mexican manufacturing industries employ intensively the capital factor in the sectors considered as technologically advanced; while labor factor is the central input in the less technological developed industries. As a consequence, we can assume that technological competitiveness of the high and medium high technological sectors grew unlike medium low and low tech sectors. Besides, just like in 1985, industries, in general, seem to distribute along the map implying notable disparities; but, in contrast, distances among them are relatively less extensive. In particular, high and medium-high technology industries are significantly closer or, more exactly, are in the same zone of the map; which implies industries have reacted to the technological change and international conditions (like product relocalization, the merge of new industrialized countries, etc.) in the same way, allowing them to obtain a similar export success. As previously stated, the SOM algorithm grouped high and medium-high tech industries relatively closer among themselves. Inside the first group are Pharmaceuticals (2423), Computing machinery (30), Medical and precision and optical instruments (33) and Aircraft and spacecraft transport equipment (353); while Motor vehicles (34), Chemicals excluding Pharmaceuticals (24-2423) and Machinery and equipment (29) are inside the second one. Again, we can assume that industries share similar characteristics in terms of innovation capacities, corporative strategies and are probably influenced in the same way by some indicator associated with market structure, cost or foreign demand. Apart, practically all of the indicators have different effects over the industries; although variations in most of the indicators have not a clearly distinguishable pattern. Product differentiation determines export competitiveness (Figure 3a), where the distribution of the industries allows us to distinguish a big group of them affected similarly by innovation product. Nevertheless, medium-high and high technology industries seem to be influenced more by this indicator than any other industry. Again, Figure 3a, reflects how the industries with major exports values are mapped more or less together at the bottom and at the left part of the map, leaving three isolated industries (30, 351, and 352+359). The exporting industries with relative poorer performance in the US market appear in the rest of the map. In opposition, market power appears to influence positively just a few industries -Building and repairing of ships and boats (351), Railroad transport equipment (352+359), Spacecraft transport equipment (353), Computing machinery (30), Electrical machinery apparatus (34), and Radio, television, and communication equipment (32), have an advantage in the US market. Accordingly with the SOM (Figure 3b), the industries where strong oligopolic competence exists are located at both, right and left, upper corners and at the central part of the map. This kind of market structure can lead the major exporters to price discrimination practices, that is, to establish higher prices in the domestic market and lower prices in the foreign ones, as a strategy to access the international market. Nonetheless in a big number of industries, perfect competition operates. Thus, we could assume that firms market power rise the export performance as well as product differentiation. On the other hand, the SOM suggests that the level of exports is directly linked to external demand and foreign direct investment in relatively few industries. Figure 3c distinguishes a cluster of industries located at the lower left corner. These say that US demand conditions influences mainly the exports of Motor vehicles (34), Radio, television, and communication equipment (32), Machinery and equipment (29) and Textiles, apparel, leather, and footwear (17+19). In contrast, FDI affects positively Motor vehicles (34), Machinery and equipment (29), Chemicals excluding Pharmaceuticals (24-2423) and Food, beverages, and tobacco (15+16), as it can be seen in Figure 3d, where one cluster located in the bottom of the SOM, towards the left side, stands out. Alternatively, as we can expect, both indicators have a limited impact in the export performance boosting not just few industries, but also the value of their exports. Figures 3e and 3f show the relative unitary labor cost and the capacity production. The former, suggests cost dimension negatively affects all the industries in terms of their exports (except three industries 17+19, 30, 32). In particular, it shows one cluster formed by Coke and refined petroleum products (23), Rubber products (25), Fabricated metal products (28) and Chemicals excluding Pharmaceuticals (24-2423). In contrast with the 1985 case, apparently fewer industries are affected by this variable, suggesting that cost competitiveness has stopped to be a central determinant of export success. This variable seems like a central factor for the exports -just four industries are negatively related with this indicator (17+19, 20, 32 and 31)- which means that the scale of production gives an advantage to the industries. In particular, this dimension appears to be fundamental in the case of Motor vehicles (34) and Food, beverages, and tobacco (15+16) and in less magnitude for Other non-Metallic products (26), Basic metal (27), Pharmaceuticals (2423), Coke and refined petroleum products (23), and Aircraft and spacecraft transport equipment (353). In between the extremes of success and failure in export performance at the different ends of the map, there are intermediate industries with acceptable level of exports. Hence, product capacity and in a less extends cost, are fundamental determinants of the manufacturing exports although the dimension of the map does not seem to reflect the exporting success of all the industries. Finally, we consider the spillover effects (Figure 3g) over the exporting industries; which is surprisingly a source of competitiveness for a reduced number of industries, restricting the export performance in a aggregate level and by industry. In fact, following the results of the SOM algorithm, just Machinery and equipment (29) and Computing machinery (30) benefit from the multinationals technology. It is worth mentioning that, once again, the greater effects of these indicators do not occur in the major exporting industries.

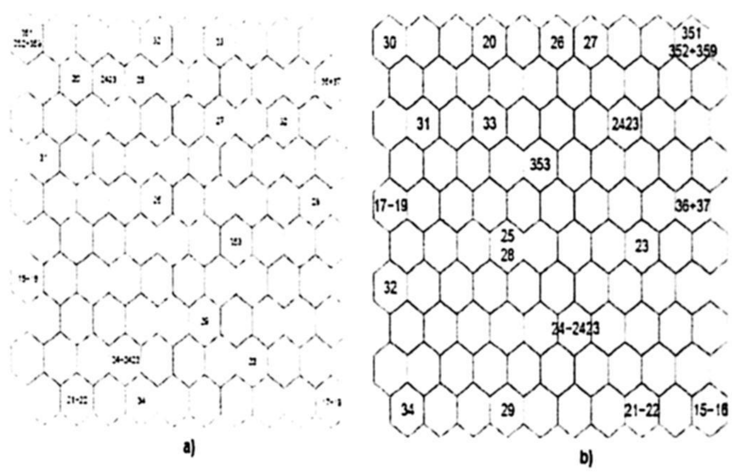

Fig. 1. SOM obtained for exports in 1985 (a), and in 2006 (b). Labels indicate the kind of exportation (see text).

4 Conclusions

In this document we have shown that the SOM can be used as an alternative and effective tool for economic analysis, in particular for cluster applications. Our results have demonstrated the efficacy of this approach in explaining the export

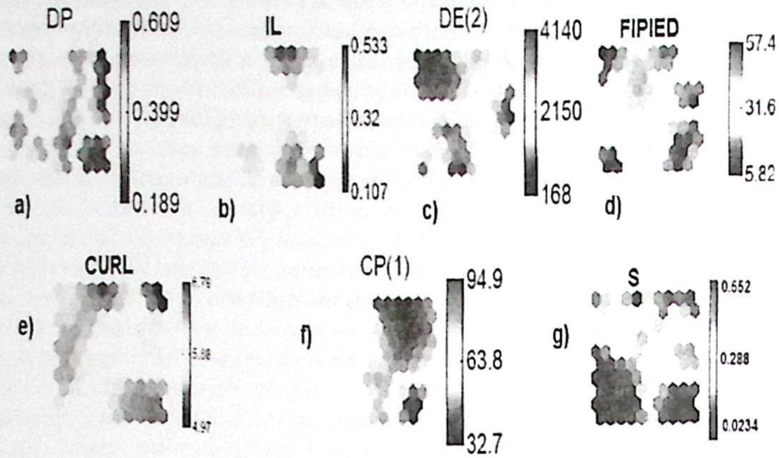

Fig. 2. SOMs for 1985. It is indicated the level of some of the variables that define the multidimensional space. DP: Product differentiation xi; IL: Lerner Index; DE(2): Foreign demand (US imports); FIPIED: Foreign direct investment; CURL: Relative Unit Labour Cost; CP(1): Domestic production capacity (product volume index); S: Technological spillovers.

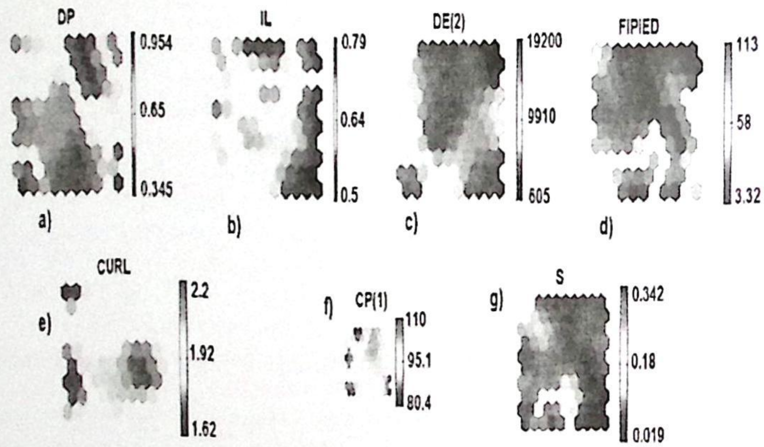

Fig. 3. SOMs for 2006. It is indicated the level of some of the variables that define the multidimensional space. DP: Product differentiation xi; IL: Lerner Index; DE(2): Foreign demand (US imports); FIPIED: Foreign direct investment; CURL: Relative Unit Labour Cost; CP(1): Domestic production capacity (product volumen index); S: Technological spillovers.

performance of manufacturing industries classified in concordance of their technological intensities. Then, based in an abundant set of variables associated with different aspects of the export process that includes technological capacities, market structure, external demand, labor cost, foreign investment, scale economies, among many others, we built a map of export performance. The set consisted of 80 indicators which described different aspects of the Mexican export success. The SOM algorithm determined the similarity between various attributes and performed the clustering of similar industries. The SOM methodology offers the economist a different perspective for the export behavior interpretation. Particularly, the SOM has great utility because it reflects two aspects of export performance of Mexican industries. First, industries are distributed along the map implying there are notable disparities among them. Principally, the export performance map is derived from a set of variables that affect in different ways -in magnitude and direction- the industries. We think this is the main reason of the dispersal distribution of the industries in the SOM. In other words, each industry has a relative export success that depends on different variables that hardly allows us to group them in defined clusters. Second, despite these differences, some industries are relatively near to each other which allow us to suggest these industries, and some of its firms, share characteristics in terms of export success. Finally, the SOM analysis finds out that in 1985 industries did not show a clear technological pattern for the considered industries. However, this situation has tended to change in 2006, implying that high and medium-high tech export industries exploit in major grade their technological capacities as a form to compete in the US market.

References

1. Kohonen, T. Self-Organizing maps. 3rd. ed. Springer-Verlag. (2000).
2. Cottrell, M. Fort, J.C., Pagés, G. Theoretical aspects of the SOM algorithm. Neurocomputing 21 (1998) 119-138.
3. Ritter, H. Self-Organizing Maps on non-euclidean Spaces Kohonen Maps, 97-108, Eds.: E. Oja and S. Kaski, (1999).
4. Vesanto, J. Som-based data visualization methods. Intelligent Data Analysis, 3(2):111126, (1999).
5. Rissi, F. Visual Data Mining and Machine Learning. ESANN'2006 proceedings - European Symposium on Artificial Neural Networks Bruges (Belgium) (2006).
6. Kaski, S., Kohonen, T. Exploratory data analysis by the self-organizing map: strcutures of welfare and poverty in the world. In Apostolos-Paul N. Refenes, Yaser Abu-Mustafa, John Moody, and Andreas Weigend (Eds.) Neural Networks in Financial Ecnonomy. Proc. of the 3rd. Int COnf. on Neural Networks and Capital Markets. World Scientific. (1996).
7. Deboeck, G. Kohonen, T. Visual Explorations in Finance with Self-Organizing Maps Springer. (1998).
8. Grossman, G.,Helpman, E. 'Technology and Trade'. CEPR Discussion Paper no. 1134. London, Centre for Economic Policy Research. (1995).