# Local sustainability and competitiveness: the case of the ceramic tile industry

Margherita Russo
Peter Börkey
Emilio Cubel
François Lévêque
Francisco Mas

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## 1. INTRODUCTION

### *1.1. The issues: employment and sustainability*

This study intends to offer a micro-economic approach to the impact of environmental policy on small and medium size firms, located in different EU regions, belonging to different industrial organisations, exposed to different environmental pressures (from society and institutions) and achieving different economic and environmental performances.

In this framework we intend to examine the importance of regional and local policy measures and their consequences on employment.

The study will focus on three key issues.

First of all, in explaining the environmental performances we must take into account the ways in which technical change, the learning process, interactions among agents and institutional settings affect and are affected by the behaviour of economic agents (firms, consumers). Here not only should questions of the technical and economic feasibility of reducing environmental impact factors be considered, but also the process of investment decisions related to the adoption of technologies that influence the environmental performances of firms. In this analysis, the timing and the sequence of technical change should be examined by considering the way in which firms react to whatever appears to them as a constraint[1] and the role of uncertainty[2]. In particular, uncertainty plays an important role in characterising the particular pattern we find in the diffusion of new techniques; moreover, path-dependence appears to be a relevant phenomenon in explaining the spread of new techniques.[3]

A second theoretical issue emerges as a background of the analysis of the environmental performance of certain production activities in a given area: environmental problems may arise from the concentration of an activity in a limited area. Hence, in examining the environmental and economic sustainability[4] of industrial activity we have to consider the technical and economic opportunities of delocating some of the production activities now concentrated in a given location. Furthermore, "local sustainability" may refer to different "loci": the locations of the production activity, the locations where resources used in that production derive from, the locations where the output of that production activity is used, the locations where residuals of production are stocked and the locations where the depleted product is stocked. It is the existence of a multiplicity of locations related to the production and consumption of goods that has suggested submitting all the local sustainability issues related to a given product to an analytical process known as "Life Cycle Assessment".[5] For the purposes of this research, the LCA approach provides a helpful starting point in defining the product system boundaries and the environmental impact factors.[6]

[1]On this point cf. Rosenberg (1963).
[2]Cf. Rosenberg (1982) and (1994).
[3]Key references are the seminal articles by Arthur (1989), David (1986). Rosenberg (1994) makes more explicit the analytical nexus between path-dependence processes and historical analysis of technical change.
[4]The idea of environmental sustainability, which entered the economic analysis of "sustainable growth" in the 1970s, is far from being well formalized. By and large, it implies that we should take into account the long run consequences of today's activity without robbing the future to the benefit of the present. Economists generally debate this issue within a general equilibrium framework in which they consider the environment as part of the endowment of resources whose value must be defined. Any general equilibrium model takes resources as given and, when natural resources or, more generally, the natural environment are considered, the point becomes how to keep the rate of use of these resources leaving them useable by future generations: time horizons and discount rates then become a crucial issue. (Cf. Heal, 1995). Beyond any other consideration, a general equilibrium framework that must take account of technical change is not useful in our analysis.
[5]"Life cycle assessment" is a methodology adopted to assess the environmental impact of whatever end product. According to this methodology it is necessary first of all to define the boundaries of the product system under investigation and then to consider all the factors related to that product system, from "cradle to grave", which have an environmental impact.
The LCA methodology assumes that, for each particular stage, every location has the same characteristics. In all the cases in which the environmental impact factor of a particular stage of the product system is restricted to a specific loca-

External economies and diseconomies of agglomeration are the core of the third analytical issue under consideration. When the existence of specific production locations is considered, an explanation of the factors favouring concentration is crucial, otherwise it would be impossible to assess feasible delocation measures of some of the activities now concentrated. The nature of the external economies must then be investigated and, in this perspective, the literature on industrial districts is an important benchmark.[7]

### *1.2. The case study: the ceramic tile industry in Italy, Spain, Germany and France*

We consider the production of ceramic tiles in four EU countries: Italy, Spain, Germany and France. At present Italy is the world leader in the ceramic tile market, followed by Spain and Portugal. The latter has recently become a very strong competitor in the world market, but at present there are not available data on Portugal, this is why we have not included Portugal in our case study. Ceramic tiles, used to cover floors and walls (internal and external), are produced by these four countries for domestic consumption and for export in the world market (mainly EU and USA). Other non EU countries (like China, that has rapidly become the first world producer, and Brazil) produce only for the home market.

In 1994, total employment in the industry in the four countries was about 58,251 and total output was over 923 million square meters of ceramic tiles. As shown in table 1, Italy and Spain are the biggest producers and account for almost 70% of EU and North American markets for ceramic tiles. By and large, the world ceramic tile market is segmented into two ranges of price and quality that see the presence of Spanish products with medium-low price range in one segment, and the Italian products with medium-high price range in the other segment.[8] A small share of the world market (less than 5 per cent) regards ceramic tiles for special uses, such as swimming pools or the large surfaces in hospitals or airports: some German firms are very active in this segment of the market, even though the biggest Italian and Spanish firms are trying to increase their share.

Since price is a key competitive factor in the medium-low segment of the market, then process innovation is crucial for it allows the adoption of techniques reducing production costs. In the high segment of the market, the competitive factors are both the design and the technical characteristics of tiles; hence, product innovation becomes the most important competitive factor.

The general trends in output and employment are different in the four countries. In the last ten years, within the general increase in the world ceramic tile market, Italy and Spain have seen a great increase in output and a very moderate increase in employment; by contrast Germany has continuously declined in both output and employment and France, after a general decrease both in output and employment, increased output between 1990-1994.

Ceramic tiles in Italy and Spain are produced by large and small firms located in a limited area, while in Germany and France firms are generally large and are scattered all over the country.

Production technologies and pollution abatement technologies for the ceramic tile industry are produced in Italy in the same area where ceramic tile firms are located. No other country has a significant presence of firms producing machines or pollution abatement technologies. In 1994 these firms were 225 in number with about 8,000 employees. In the same year, firms producing pollution abatement technologies were about 20 in number with fewer than 250 employees in total.

tion, the methodology must specify a "scale equivalence" of environmental impact, *i. e.* a criterion that makes different locations comparable with regard to the impact that the various factors generate on the environment of these locations. The definition of such a criterion is beyond the remit of this research, even though we find that the physical characteristics of different production locations give rise, for the same factor (let us say fluoride emission), to different environmental impacts in different locations. In our case, in fact, the definition of an equivalence scale should include and weigh not only the differences in terms of climate, morphological characteristics of the geographical areas under consideration, but also the historical, social and political differences that are crucial in interpreting the perception by the members of the different communities of what is the environmental impact of a specific factor. Given these conditions, it is clear that the definition of an equivalence scale is not a useful analytical tool, and it will not be adopted in this research.

[6]Issues related to global sustainability are those defined by the Rio Conference in 1990 (CO2 emissions, ozone) and this study will not consider them as such.

[7]In particular, the reference here is to the notion of industrial district as defined by the Italian economists Giacomo Becattini and Sebastiano Brusco; cf. Becattini (1990), Brusco (1990), Bellandi (1994), Dei Ottati (1994), Russo (1996).

[8]Cf. Assopiastrelle-Prometeia (1995).

### *1.3. Methodological aspects and data sources*

The issues under consideration need to include the following analytical and methodological aspects.

(a) The environmental emissions considered in the study are those related to the production of ceramic tiles: from the preparation of raw materials within the factory up to warehouses where final output is stored. Moreover, the environmental impact of transport of raw materials to the factory and of end product to the retailer is considered.

(b) The units of investigation are the tile producers, the producers of production technologies and the producers of end-of-pipe technologies. Interrelationships between the various types of producers have been examined to highlight the process of generation and adoption of technologies that reduce the impact of tile production on the environment.

(c) The characteristics of firms operating in different industrial organisations have been investigated with regard to internal structure (level of vertical integration, process and product specialisation, labour organisation), interfirm organisation, innovation behaviour, environmental performances and competitiveness.

(d) The different environmental performances of firms in the four countries have been compared.

(e) The importance of local and regional public authorities has been verified for the following key issues:
- the drawing up and enforcement of environmental regulations;
- their influence on employment through qualification measures or other types of direct or indirect measures;
- the role they play for strengthening (improving) competitiveness of firms in the sector.

(g) The role of environmental pressures from organised groups (trade unions, citizens) has also been examined with regard to the emergence of environmental regulations.

(h) To obtain an idea of trends in different scenarios, prospective questions have been outlined with respect to changes in national competitiveness, employment and innovation due to new, more stringent regulation of the environment.

The sources of data are, in the main, the associations of ceramic tile firms in France, Germany and in particular those in Italy and Spain that have carried out a wide range of studies that examine both production and environmental aspects of ceramic tile manufacturing. With regard to ceramic tile production in the Sassuolo district (Italy), there are several European projects that provide thoroughgoing studies on environmental issues[9] and on transport problems[10]. Moreover, since the 1970s, the local health authority monitored environmental impact factors in the district and has disseminated several summary reports[11].

Besides data taken from these sources, an important source of information has been provided by several interviews with experts and ceramic tile firms in the four countries, and, in Italy, with firms producing production technologies and producing pollution abatement technologies.[12]

### *1.4. The structure of the paper*

Section 2 illustrates the factors of environmental impact related to the various stages of the production process and summarises the best practice technologies now available to reduce the impact of those factors.

Section 3 considers the ceramic tile industry in each country by taking into account the history of this industry and describing the industrial structure (in terms of size and location of firms, types of products, markets), firms' strategies (in terms of interfirm competition, and product and process innovation), the composition of direct production costs, and public measures which are of benefit to ceramic tile firms.

[9]Cf. ISTRICE (1990), and the Thermie programme action on "Energy saving methods in the ceramic tile industry", (1993).
[10]Cf. Demetra (1994).
[11]Cf. Busani, Bedeschi, Capuano (1993), and Busani, Timellini (1994).
[12] Cf. annex with the list of people interviewed.

Section 4 describes the industrial structure of the Italian machine producers and of pollution abatement technologies for ceramic tile production. The internal organisational structure of these firms is examined together with their strategies. Interrelationships between firms are examined to highlight the process of creation of environmental technologies suited to the production of ceramic tiles.

Section 5 describes the environmental pressures and the environmental regulations in the four countries. The environmental performances of ceramic tile firms are discussed with regard to the limits now in force in the four countries. Moreover, we estimate direct and indirect employment induced by environmental pressures and on abatement costs. Emerging environmental issues are indicated.

Section 6 presents the conclusion of our findings dividing them into two distinct dimensions: the present issues and some alternative scenarios. First of all, we discuss the impact of environmental regulations on employment, abatement costs and competitiveness in the production of ceramic tiles. Second, we discuss the consequences of environmental regulations on competition and employment in two alternative scenarios: the first considers the present trends in the ceramic tile industry and in environmental regulations in the four countries; the second scenario discusses the cases of a reduction of present limits.

## 2. ENVIRONMENTAL IMPACT FACTORS AND POLLUTION ABATEMENT TECHNOLOGIES

### *2.1. The technical characteristics of the production process*

Before discussing the environmental aspects of ceramic tile production, it is useful to provide a brief overview of the production process that presents the main production techniques and the main products.

The first stage is the preparation of the raw materials by a dry process of grinding the clay into a fine powder that is then moistened and pressed into tile shape. Another technique of preparing raw materials is a wet method where first raw materials are milled, then fluidified and finally sprayed into a spray drier to obtain the finest powder to press into shape. The shape of tiles may be obtained not only by pressing the fine powder into the die, but also by extrusion. Both the pressed and the extruded tiles are then fired to produce "biscuit". The biscuit is then sorted, glazed and fired again and finally grade sorted to give the final product. This process of production is called "twice-firing", as opposed to an alternative process in which tiles are glazed directly after the pressing operation and then fired only once: hence the name of the "single-firing" process of production. Firing techniques now in use are twofold. The first uses traditional tunnel kilns, where kiln cars loaded with piled tiles enter the kiln; with the second, a single stratum of tiles enters the kiln: in this way the time of second firing is reduced from 16 hours to 30 minutes ("fast firing"). Figure 1 represents a detailed scheme of the single-firing and twice-firing processes of production. Ceramic tiles produced by both processes might be further decorated and fired again to obtain special decorations; this process, known as "third fire", is adopted to decorate very small quantities of tiles. Porcelain stoneware tiles are polished instead of glazed, as schematised in figure 1.

Technical opportunities for vertical disintegration allow that the twice-firing production process can in principle easily be split up after the grinding operation, the first firing, the biscuit sorting, the second firing and the third firing; but problems of transport make it impossible to separate pressing from the first firing and glazing from the second firing. The single-firing process is, by contrast, conceived as an integrated production line from the pressing to the firing operation, and thus the only possible breaks in the whole production process are after the grinding operation and after firing.

These technical opportunities for separating the various operations in both processes have indeed been partially exploited. The stimulus to vertical disintegration in these cases has come both from cost advantages and, more important, from advantages in terms of product and process specialisation that vary from country to country.

In the last twenty years, both in Italy and Spain, the relative shares of output of single-fired and twice-fired tiles have radically changed: single-fired tiles, whose production started and widely increased during the 1970s, now represents about 70-72% of the total output, whereas twice-fired tiles, which represented until the mid 1970s the predominant type of ceramic tile, are now at about 20% of total output.

The remaining types of products are extruded tiles (obtained by the extrusion process, both with single- or twice-firing), and porcelained stoneware, an emerging type of product.[13]

### *2.2. Factors of environmental impact*

In this research, the boundaries of the ceramic tile system include the various stages of the production process from the preparation of raw materials within the factory up to the warehouse where final output is stored. We do not take into account the downstream stage of disposal of used tiles because ceramic tiles are inert products, and their replacement is not frequent.

[13]From a technical point of view, ceramic tiles might be classified, according to the European standard, into different categories according to the water absorption capacity and the process of shaping (by pressing or extruding). However, economic data based on that classification are not available and hence it will not be used in this study.

We shall represent the ceramic tile system so defined by drawing a flow chart (figure 2) that incorporates all relevant processes. This flow chart does not represent the transport of raw materials to the factory and the transport of final product to the retailer, both having a significant environmental impact that will be considered in our analysis. Moreover, to allow for greater readability, we have omitted the specification of electrical energy, which enters every stage of the production process, and the thermal energy, which enters every stage but glazing and selecting. It should also be observed that the flow chart does not include time scale and location which are important variables in fully assessing the environmental impact of the various factors.

Here they can be summarised as follows:

- air emissions: dust (to different degrees emitted at almost all stages of the production process), lead and fluorine compounds (contained in enamels and partly in raw materials) are emitted from firing processes, organic substances used to correct glazes rheology;
- water consumption: water is an input in the preparation of the fluid mix of raw materials (slip) then dried and reduced to the required size by the spray dryer, and in cleaning the glazing lines and the glaze mill department;
- water emissions: emissions contain Pb, Zn, suspended particles, boron, colouring pigments;
- residuals: broken tiles (largely inert waste), depleted lime (toxic waste), eluates from treated boron (toxic waste);
- electric energy consumption: automated machines and cleaning devices;
- thermal energy consumption: gas fueled spray-dryers, dryers and kilns;
- transport: mobile sources generate CO2 emissions and congestion;
- noise: grinding stones, various moving parts of the presses, fans, electrical engines and then also the air and water abatement devices produce noise some continuously, others intermittently.

As figure 2 shows, every stage of the production process has polluting air emissions (cold and hot) and water emissions. Moreover, this production process is water demanding for transformation operations (fluidification of raw materials) and uses significant quantities of water for cleaning glazing lines: the production of 1000 m2 of ceramic tiles needs an average quantity of 21 m3 of water (roughly equivalent to one quarter of the average annual per capita consumption in an Italian city of average size).[14] Roughly speaking, if recycling of water were not adopted, the water consumption for the annual production of tiles in the Italian district of Sassuolo would be equivalent to that of a town of 90 thousand inhabitants. Finally, production residuals and abatement of toxic residuals raise problems of proper storage (both within and outside the firm).

The level of automation of the ceramic tile production process leads to the intense use of electric energy: over the last decade the new techniques have reduced the quantity of electric energy per unit of output, but the adoption of end of pipe technologies tends to increase this consumption.

### *2.3. Emission abatement technologies*

Dust sucked in is cleaned with a dry method that uses sleeve filters or with a wet method that adopts the Venturi tube. Chemical reagents are used when required and cyclone chambers are adopted as a sedimentation technique.

Water recycling for reuse requires a certain degree of purification to avoid smells, corrosion, reduce concentration of particles in suspension. Cooling towers are used for water circulation in closed circuits. Treatment of waste water requires collection in tanks, sedimenters (to separate thick particles), homogenising tanks (stirrer) and reaction tanks (for coagulation, neutralisation and flocculation), clarifying to separate solids. Boron treatment devices are required to purify waste water from glazing.

Solid waste is partly identical to urban waste (packing and waste from pallets, some cleaning and laboratory maintenance materials). Part of the waste is inert waste produced to a greater or lesser extent at all stages of production: it is collected and 90% of it is conveyed to internal recycling.[15] Toxic and dangerous waste is produced in the treatment of waste water and air emissions.

[14]Our elaboration on data taken from Busani and Timellini (1994).
[15]Non-fired broken tiles are not inert waste and are generally recycled. They represent a small part of total residuals.

Characteristics vary according to use, but in every case special treatment is required for its disposal. It might be partly recycled.

Noise might be reduced either by more efficient insulation of the individual machines, by adopting noise reduction devices, but also by a better design of the overall plant.

Since end of pipe solutions, when they have extensively been applied, have reached these limits, no technological process innovation which would lead to an important decrease of emissions seems to be available in the short term.

### *2.4. Energy saving techniques and co-generation of electrical and thermal energy*

In the production of ceramic tiles, energy consumption per unit of output has greatly decreased in the last ten years. This has been the result of a general spread of fast firing techniques, of the improvements of the technical characteristics of the individual machines[16] and, more recently, of the adoption of co-generators.

Co-generation of thermal and electrical energy is a technical issue which is well documented with regard to ceramic tile production[17]. In general, co-generators are adopted in cases when there is a contemporaneous need of electrical and thermal energy, as in the case of spray-dryers where a turbine is moved by the hot air generated in the combustion chamber fueled by natural gas. When leaving the turbine that hot air (about 500°C) goes into the spray-dryers for the drying of the slip. A burner may be needed to reduce or increase temperature as required in spray-drying. The adoption of a co-generator requires the use of a continuous mill, so that the plant does not have to be stopped to fill and to empty the mill, as was the case with the mills previously used. In this way the co-generator makes it possible to produce almost 70% of the electrical energy needed for the continuous mill. In any case, the adoption of co-generators is made possible by the (only recent) opportunity of selling excess electricity produced at peak times to the electricity company. This opportunity has provided a strong stimulus for the adoption of co-generators.

[16]See, for example, the project sponsored by the Italian energy agency, Enea, in collaboration with the Italian machine producer Sacmi, to realize a press with lower energy consumption.
[17]Cf. Nassetti (1995) and references quoted there.

## 3. THE CERAMIC TILE INDUSTRY IN THE FOUR COUNTRIES

### *3.1. Italy*

In 1994, Italian firms produced 510 million m2 of ceramic tiles, almost 80% of which were produced by 190 firms in the ceramic tile industrial district formed by ten Comuni in the provinces of Modena and Reggio Emilia. The other 21 firms of the Emilia Romagna region produced less than 9% and the 134 firms outside the region (mainly Lazio and Campania) produced the remaining 11%.

#### *3.1.1. History*

Emerging at the end of the 1940s, large scale production of ceramic tiles thereafter increased rapidly, especially in the period 1960-80, which witnessed the increase of output from 37.8 million m2 in 1960 up to 355 million m2 in 1980[18]. In the same period the proportion of exports went up from 3,5% in 1960 to 45% in 1980, giving Italy a clear lead in the world market. In particular, the 1960s and 1970s witnessed the easy entry by many new firms into the ceramic tile industry (up to 509 firms by 1976), both because the initial investment required for a factory of minimum efficient size was - at that time - very low and because the know-how was not difficult to acquire.

A crucial factor in the development of ceramic tile production has been the increase in both domestic and international demand. The sharp increase in domestic demand was induced partly by changes in the Italian housing legislation[19] of the early 1960s, and partly by changes in the technical and aesthetic characteristics of ceramic tiles that enabled this product gradually to enter into competition with the flooring and wall-covering materials traditionally used in Italy, such as graniglia-tiles, marble and linoleum.

The greater part of the increase in ceramic tile production has been provided by the building of new factories, or the expansion of existing ones, in a very limited area in the provinces of Modena and Reggio Emilia. Since the middle of the 1960s, the two provinces accounted for more than 70% of the national production of ceramic tiles and 4 out of 10 ceramic tile factories are in the six *Comuni* [20] that constitute the core of the ceramic tile industrial district.

The main factors in the development of ceramic tile production in the industrial district have been the following: (a) easy access to raw materials (different kinds of clays) in the mountains in that area; (b) an abundant labour force owing to the depressed conditions in that area during the 1950s; (c) long and medium term credit facilities, lasting till the middle of the 1970s, for new enterprises in depressed areas[21]. These factors have induced a peculiar development process strongly marked by the interrelationships between ceramic tile firms and producers of machines for the ceramic tile industry that grew in the district. This has made possible a high pace of technical change which has contributed to a large extent to the success of the Italian ceramic tile firms in the world market.[22] Also located in Sassuolo, the core of the ceramic tile industrial district, are firms that produce machines for ceramic tile production, enamels and all the required packaging materials. Moreover, transport services and indirect sales services are organised by firms located in the district.[23]

Until the beginning of the Seventies the entrance of new firms in the ceramic tile sector was easy: the investment of a factory of minimum efficient size was relatively small, technological knowledge was easily acquired, labour force was abundantly found in the South of Italy, where unemployment rate was (and is still now) very high. At the end of the Seventies, single firing

[18] Cf. Assopiastrelle (1983).
[19]There was an allowance for building non-luxury houses. One criterion used to classify houses was the amount of ceramic tiles used. The abolition of this rule allowed the increase in the demand for ceramic tiles in every type of house.
[20]*Comune is* the smallest unit of local government in the Italian administration system.
[21]Several *comuni* of the district were included in the list of depressed areas that benefited from facilities provided by the laws n. 635/1957 and 623/1959.
[22]For a detailed analysis of the process of technical change in the industrial district, see Russo (1989).
[23]Cf. Russo (1990).

technology[24] was rapidly adopted by several firms to reduce production costs. It should be noted that, from a technical point of view, the type of output produced with the single firing technology is different form the one obtained with the two firing technology. But quite soon it emerged the possibility of selling both single and two firing tiles in the same market segment. Obviously, the two products had two different prices, but that difference was less than the difference in terms of production costs. This was a strong stimulus for the adoption of single firing technique by several firms that were specialized either in the biscuit preparation or in the glazing stage. These types of firms were of small size and heavily dependent on those firms producing both stages[25]. Many specialized firms were enable to cope with the need of internal technological and organizational restructuring induced by the adoption of the new technology and this is why the number of firms strongly decreased at the end of the 1970s.

In the years 1982-1984 ceramic tile firms had to cope with a financial crisis also due to wrong investments[26]. In that period , the process of concentration within groups had a significant turn. This is why even though the number of firms decreased, the number of production sites diminished to a lesser extent; infact, previously independent firms became production units of existing firms.

Changes occurred during the 1980s strengthening tendencies which emerged in the previous period: the number of producers has drastically decreased, while output has been constantly increasing; international competition has increased because of the entrance of new producer countries; the necessity of integrating techno-productive strategies and sales strategies has become more urgent; finally, even though the presence of small firms is still very high, concentration has increased leading to the formation of a group controlling more than ten per cent of total Italian production.

With regard to machine producers, after having become leaders in the world market, they are now facing a reduction in domestic demand and find a greater need both for specialisation in the various export markets and for diversifying towards other users. The increased share of exports of Italian machines for ceramic tile production may be an important stimulus for the Italian ceramic tile firms in that it increases competition with other countries, such as Spain, which can compete with Italian producers by adopting the same technology. Moreover, diversification of machine producers strengthens the hypothesis that the ceramic tile production system has the capacity to react positively to changing economic conditions, and to graft new productions onto the existing ones. As stressed by the theoretical discussion on industrial districts,[27] this is an important sign of the vitality of a production system.

#### *3.1.2. Industry structure, employment, markets*

In the last forty years, output and labour productivity have increased continuously, while the number of firms and employees has decreased, mainly in the district (table 2).

The majority of ceramic tile firms have had less than 100 employees and the main products are: single-firing, twice-firing, porcelain grès. Since the middle of the 1980s the overall increase in production has been largely due to the increase in single-firing tile production, which has become the main kind of tile produced. A significant increase in unglazed porcelain tiles has been registered in the last five years.

Italian firms are exporting medium-high price ceramic tiles towards markets where Italian quality and design are much appreciated. The main export markets (table 1) are Europe (mainly Germany and France ), and America (mainly the United States). The export data (table 2) show a positive trend in the last fourteen years and a significant leap in 1993, when exports have more than compensated the decrease in sales on the home market.

#### *3.1.3. Firms strategies and competition*

[24]Note that at that date the single firing technology still adopted the tunnel kiln with a firing time of 16 hours. The firing time was reduced to 30 minutes only in the second half of the 1980s when the fast firing technique spread.

[25]In my paper on Research Policy (1985) I provide a more detailed explanation of this point.

[26]For example, in several cases it was very heavy the effect of big investments in a type of one-layer tunnel kiln that adopted trolleys instead of rolls. This kiln was very inefficient and required several costly changes and finally was substituted with the roller kiln.

[27]Cf. Becattini (1990).

To recover from the financial problems emerging at the end of the 1970s, many ceramic tile firms formed groups based either on reciprocal shareholding or trading links. The existence of such groups in this industry was not a completely new phenomenon. But, whereas in 1973 no more than 15% of the ceramic tile firms in the provinces of Modena and Reggio Emilia were operating in 5 groups, in 1979 almost 50% of the firms were linked to 12 groups; at present, the six biggest producers (Marazzi-Ragno, Iris, Cisa-Cerdisa, Riwal, Piemme, Atlas-Concorde) have a share of production of about twenty per cent (80% being produced by about 200 firms of medium and small size). In general, 40 groups control 70 to 80% of the firms in the industry and concentration will increase in the coming years. The strategy of increasing overall size is crucial in gaining all the economies of overall size, diversification and vertical integration control from raw material to sales organisation .

In general, the various groups have several trade marks, that characterise different qualities of tiles for different markets (different countries, or different uses) and each firm within the group specialises in one or a few types of products; very special pieces are produced by craftsman firms. Sales of the different trade marks are organised separately within the group, because, before the merger, the firms (joined under the same ownership) had different types of client.

With regard to the forward vertical integration of the production of third-fire, the strategies of the groups are different. In some groups, third-fire is partly internalised so as to have an advantage for just-in-time production. In other cases, it is preferred to subcontract to third-fire firms: within the district of Sassuolo several independent third-fire producers compete with each other (there were over 60 of them in 1994) and this makes it possible to have strong stimuli on specific technical and design solutions, not always easy to obtain internally. In the case of third-fire firms that are very skilled in making some specific products, the ceramic tile group may benefit from a stronger direct link with them by buying an ownership share (not necessarily a majority one).

All the groups tend to reduce import dependence for raw materials from Germany, by increasing the use of those found in Sicily; they generally buy enamels, pigments and "frits" that are produced at a very high minimum efficient size from multinational firms externally. Nonetheless, internal production of glazes is a competitive factor because the glaze, together with design, is a crucial factor in product innovation.

All ceramic tile firms, not only the groups, offer machine producers the opportunity of experimenting new technologies in advantageous conditions and feel free to contact whatever machine supplier they want. Only one big ceramic tile group, Iris, has an internal department that develops new processes and products: this is considered a possible barrier to imitation. In fact, innovations introduced by larger firms are generally imitated by other firms, even though the imitator will not always compete on the same market. This process of innovation and imitation may not be generalised to every type of innovation. In some cases the product innovation cannot easily be imitated by competitors because it needs complementary changes in the production technologies or in particular inputs. But, since production technologies are generally produced not exclusively for one particular user, a complementary change in production technologies can also be introduced by other producers that try to make up for the advantages obtained by the initial innovator. In all events, the time lead in this dynamic process gives an advantage to the initial innovator. Product and process innovations give a competitive edge in the international market where the ceramic tile firms of other countries are not yet able to derive benefit from positive interactions with the machine producers located in the Sassuolo district.

### *3.2. Spain*

#### *3.2.1. History*[28]

During the 1970's, after decades of slow growth, Spanish ceramic tiles production took advantage of the adoption of the most up to date firing techniques, which made it possible to widen the range of products. However, the significant change really happened during the 1980s when output almost doubled, employment decreased by 13% and exports went up from 17% to 42% of output:

[28]On the history of the ceramic tile industry in the more general economic context of the Valencia region, see Aldovini and Fontanive (1991).

a continuous increase in sales towards Europe and North America more than balanced the falling share of sales in the Middle East, a traditional market for Spanish tiles.

The most significant increase in the Spanish ceramic tile production has been achieved by the firms in the Valencia region and in particular in three *comarche* in the provinces of Castellón, de la Plana Baixa, Alcatén and de la Plana Alta, where 80% of Spanish ceramic tile firms are located. In particular, all the biggest firms are located in Castellón and Villa-Real.[29]

Four main factors explain such important changes. First of all, the resurgence of democracy has stimulated local development policies which favour small and medium size firms (see Benton, 1990). Second, in 1980 the completion of the natural gas pipeline in the province of Castellón made it possible to use a more suitable, low cost energy source for the single-firing technology, which was then emerging as an important technical change. Third, the presence in the Valencia region of abundant red clay with low organic substances led to the production of good quality single-firing floor tiles, with a better efficiency than in Italy. Since 1984 wall tiles have also been produced with the single-firing technology. The rapid spread of the best available technologies was made possible by the Italian machine producers, who started selling in Spain, offering technical assistance and opening subsidiaries in the Castellón area in order to offer maintenance service. Moreover, several firms supplying colours and auxiliary activities started to support the expansion of ceramic tile production. Fourth, the expansion in domestic demand from the building industry was a strong stimulus, especially in the period of 1985-1988 when Spanish demand grew at a rate higher than the average for the building industry in other EU countries. This was the effect of two national government plans in favour of public housing (1981-1983 and 1984-1987) and of the resurgence of tourist activity.

The big technical changes introduced during the 1980s were accompanied by organisational changes internal to the ceramic tile firms and by the birth of new firms owned by entrepreneurs with previous experience in other industrial sectors who were attracted by the expected high rates of returns on investments in the ceramic tile industry. The 1980s witnessed a high birth-rate and death-rate among companies; moreover, control and ownership of several firms became more concentrated.

### *3.2.2. Industry structure, employment, markets*

In 1994, there were 185 Spanish firms producing 320 million square meters of ceramic tiles. The size of ceramic tile firms is quite small: almost 80% of them have fewer than 100 employees and only 8 firms have more than 500 employees.

Traditional twice-firing tiles, which in 1980 were the only type of product, has now a small share of total output while fast twice-firing has an increasing share, the most important product being single-firing. Almost 5% of output are extruded tiles.

In the last ten years, after an increase in domestic sales, there has been a slowdown until 1994; in 1995-96 the increase in investments in housing suggests a probable upturn in domestic demand for ceramic tiles.

The export share of Spanish ceramic tile sales has increased up to 50% of sales in the last ten years and the main export markets are now EU (mainly France, the United Kingdom and Germany), and the United States (see table 1). In 1994 exports were 158,4 million square meters. In general, during the first half of the 1990s, the slowing down of domestic demand for ceramic tiles has been compensated by a marked increase in exports, and not only in the traditional medium-low quality segment of the market. It is worthwhile noting that, in fact, some Spanish producers who targeted the upper end of the market (characterised by large tiles, or by biscuit for twice-firing processes, or by high quality design) are on a par with their Italian competitors. Moreover, Italy is the main market outside of Spain for the sales of high quality products of the biggest Spanish producers (Porcelanosa).

## *3.3. Germany*

[29]Outside the province of Castellón there are ceramic tile firms in the provinces of Barcelona and Gerona, in Catalonia, and in Manises, in the province of Valencia.

Historically, most German firms have a long tradition in ceramics manufacturing and have stayed in their location for sometimes more than two centuries. The geographic location was traditionally determined by natural resources, which are abundant and of particularly good quality (white clay) in Germany. Many plants trace their origins to feudal manufacturers, who produced mainly tableware for their landlords.

*3.3.1. Industry structure, employment, markets*

In 1994, the total production of about 25 ceramic tile firms was 69 million m2 (table 2).[30] The three largest firms accounted for more than 40% of that figure and almost 50% of the total number of employees in the sector (4300 out of 8800). In the last ten years, the number of employees decreased from 13000 to 8800 and the tendency is further declining. The reason is a reduction in the production capacity due to a loss in competitiveness because of relatively high energy and labour costs and inefficient factory layouts due to ancient location.[31] Another critical factor in losing competitiveness, especially vis-à-vis Italy and Spain, has been a strong increase in the value of the DM: since 1993, the Lira has lost 38% of its value against the DM and the Pta/DM exchange rate was 13% lower (33% lower if compared to 1992). In the past, this led to a shift to high quality and special non-residential products (e.g., swimming pool tiles etc.) in the sector. The effects are still being felt.

In fact, different product categories have undergone different developments. The competition for small format wall and floor tiles (up to 15x20cm) being particularly severe, German manufacturers are shifting more and more of their production to larger formats (25x33, 33x44 cm and even bigger) and high quality design products, but also specialising in non-residential special tiles. Moreover, tile manufacturers in Germany produce a large amount of extruded tiles (27 million m2 in 1990) where competition is mainly among German manufacturers. Extruded tiles are used for special (e.g. swimming pools) and extreme applications (e.g. resisting frost). It appears that the category of extruded tiles is the only product type for which production largely exceeds national consumption. The better competitiveness of German firms for extruded products is also illustrated by export rates: while floor and wall tiles have an export rate of 10%, extruded products are at 40%. This means that especially for wall and floor tiles, German firms are less export oriented, but still the most important markets are in Northern Europe (France, the BeNeLux, Austria and Switzerland). This is probably due to the strong position of Italian and Spanish manufacturers in their own markets and to higher prices for German tiles.

The particular product specialisation is also the reason for the extremely low labour productivity in the German industry, which is only half as good as in Italy. Special products (e.g., swimming pool tiles) and high quality design products are much more labour intensive than the more uniform mass products. Another reason is that most German firms have larger maintenance teams, mechanics and electrical engineers included in their staff (some even have their own transportation departments). This is necessary because the Italian machine producers, selling equipment to all major manufacturers in Germany, cannot provide the same quality of service as in Italy. The geographic distance from Italy and the widespread locations of tile manufacturers all over Germany is the reason for relatively long delays (up to a week) and forces firms to carry out a bigger share of maintenance and process improvement by themselves.

German tile manufacturers have continuously been losing market shares in the home market: from 50% in 1980 it has fallen to 25% in 1994. Distribution seems to have been an important reason for lost market shares in the past years. For a long time German firms neglected booming "do-it-yourself" markets, which have a market share of 30% today and are mainly selling foreign tiles. The growth in the home market of the past years went almost exclusively through this new form of distribution and thus only benefited foreign producers.

As far as production technologies are concerned, single-fast firing has become predominant in Germany. Twice-firing is basically used in the production of highly decorated wall-tiles, while ordinary wall tiles are manufactured in single-firing (33% of German production). Almost all the

[30]The German federation of ceramic tile producers has 15 member firms with about 20 plants. They produce more than 80% of the national ceramic tile production. About 10 manufacturers are not federation members. They are partly brick producers and some of them do not continuously manufacture tiles.

[31]Only one interviewed manufacturer intended to increase its production capacity in the medium term. All the others said they would try to maintain their present production.

dinary wall tiles are manufactured in single-firing (33% of German production). Almost all the other products can be produced in single-firing as well. Fast firing was first introduced in the production of wall tiles with relatively low resistance standards in the early 1980s and then spread to high quality floor tiles. Extruded tiles had to be very thick and therefore in the beginning were inappropriate for fast firing until new body compositions were found that made it possible to obtain thinner tiles with the same technical characteristics. New technologies in the body preparation led to these new compositions. Another necessary condition for fast firing is the use of natural gas. It was already introduced in Germany with the beginning of the exploitation of Dutch gas resources in the late 1960s and early 1970s. Fast firing furthermore led to an important reduction in energy consumption. In 1987, the vast majority of production lines in Germany were already equipped with roller kilns (fast firing). Production equipment is almost exclusively bought from Italian manufacturers.

*3.3.2. The biggest firms*

The three German leaders are very different firms. Villeroy&Boch, which produces bathroom suits and tableware besides tiles, relies on a very strong trade mark and is financially independent. ABK (Agrob Buchtal Keramik GmbH) produces the same range of products, but is owned by the Cremer group, very active in the production of building materials. Boizenburg-Gail-Inax, on the other hand, specialises 100% in tile production, (wall, floor and extruded tiles); it is the merger of an East German firm (Boizenburg) with a West German manufacturer (Gail-Inax).

Villeroy&Boch, being a German company and having a very strong position in France as well, will be briefly presented here in order to give an idea of its structure. The company relies on a tradition of almost 250 years in ceramics manufacturing and therefore has a very strong trade mark (it is probably the only firm in Northern Europe to be known as a tile producer by end users). Its geographical location in the border area with Luxembourg, France and Germany has made it a multinational company with plants in several countries. Villeroy&Boch produces all sorts of fine ceramics: tableware, bathroom suits and ceramic tiles. The company runs eleven production plants in Germany (two for tile production), five in France (two of which tiles), two in Hungary (one of which for tiles), two in the Netherlands, one in Austria and one in Luxembourg. In 1994 it had 11,820 employees and tile production accounted for roughly 40% of its total employment. The company's tile sector is currently being restructured because of heavy losses in recent years, entailing a massive reduction of its staff. However, this alone does not seem to be sufficient to solve the problem. Hence, in order to make the sector profitable again, the strategy for the future is a delocation of tile production to East European countries with low labour costs.

*3.4. France*

Very much like the German tile industry, French producers are generally located near raw material sources. Many French manufacturers have a tradition in ceramics production for more than a century.

*3.4.1. Industry structure, employment, markets*

In 1994, the 21 ceramic tile producers were running 30 plants with 3700 employees and a production of 46,4 million m2. The three largest firms (France Alfa group, Villeroy&Boch and Desvres) account for more than 75% of total production and a slightly lower proportion of employees. The France Alfa group alone accounts for 39% of French production. Thus the concentration is even greater than in Germany. However, as in Germany and unlike Italy and Spain, no massive geographical concentration can be observed.

The number of employees has rapidly decreased in recent years; since 1991, 600 jobs have been lost which means 14% in just three years. At the same time heavy investments during the 1990s led to an increase in total production of 30% in just 5 years. This supplementary production was almost exclusively for the export market and did not contribute to enlarging French manufacturers' market share in their own country, which is about 30%. This seems to be due to the French producers' strategy of operating in the upper segment of the home market, while low price tiles are mainly imported. This strategy has been supported by creating a quality label: the UPEC standard. This standard attributes tiles to preferred uses (bathroom floor, exterior terrace etc.), according to the tile resistance to wear, pointed weight, water and chemicals. All major French and foreign manufacturers selling on the French market have applied for certification, because public calls for tender generally require the UPEC standard. The only organisation authorized to award these certificates is a public institution, the Centre Scientifique et Technique du Bâtiment, CSTB. The procedure includes an inspection of factories by a CSTB engineer, which causes the certificates to be expensive. This is why smaller import firms generally don't apply for UPEC.

Labour productivity in the French ceramic tile industry (12500 m2/employee) is lower than in Italy (15000 m2/employee), but some companies reach up to 24000 m2/employee. The average productivity rate is depressed by several manufacturers producing partly hand painted traditional tiles in very old factories and with old fashioned technology.

French manufacturers traditionally specialise in the production of floor tiles. About 70% of their production are floor tiles and over two thirds of these are glazed tiles. Today, all product types are manufactured in single-fast-firing roller kilns, a technology that has been introduced only in recent years. Only a couple of small firms, manufacturing traditional tiles, still rely on traditional tunnel kilns.

As in Germany, French manufacturers did not participate in the increase of the home market because they neglected "do-it-yourself" markets in the past. However, all of them are trying to strengthen their position in this segment.

With regard to export markets, during the past 10 years French exports of ceramic tiles have continuously increased, mainly in Northern Europe (Germany and BeNeLux). Clearly, French firms are not competitive enough to penetrate South European markets because of the very dominant position of local producers.

*3.4.2. Strategies and competition*

While some of the major manufacturers clearly specialised in tile production (Groupe France Alfa), others largely diversified into porcelain and bathroom suits production (Villeroy&Boch, Groupe Sarreguemines) or tile glues (Desvres).

A consolidation process took place during the 1980s. The French leader, France Alfa, was formed out of 5 smaller companies (France Alfa, Carofrance Céramique, France Cérame, Mosaïques de France and Cerabati Céramique) which are able to provide a wide range of different types of ceramic tiles (wall, floor and extruded tiles). This group is 49% owned by the French Imetal group (specialising in construction materials), the other 51% belonging to the Italian Fin Riwal, itself running several tile plants in Italy. In 1994, France Alfa group produced 18 million m2 of ceramic tiles, with a total of 1000 employees. Through Imetal, France Alfa has a backward vertical integration in raw material sources.

In the case of Desvres, the third French manufacturer, the company has recently been taken over by the Belgian Keramik group.

France Alfa, Villeroy&Boch and Desvres are partly developing their own design and glazings, but as for German firms, they rely on mostly Italian design agencies for high quality design. With regard to the smaller French manufacturers, almost all subcontract design to specialist Italian firms and most of them do not produce glazing themselves since they are not big enough to integrate this production.

Technological innovation in the machinery and kiln sector is developed in Italy and later embodied in the new equipment bought by the French ceramic tile firms who develop only small process improvements. Service delays from Italian machine manufacturers are about the same as in Germany, which requires them to run larger maintenance teams. Thanks to its Italian owner, France Alfa is in a particular situation, because it relies on Italian engineering teams from Fin Riwal for process and machinery modifications.

Competitiveness of French tile manufacturers seems to be quite good compared to Germany. Several firms are planning to increase their production capacity in the short term, their exports are increasing regularly and none of the interviewed firms said they suffered higher production costs than Italian firms: at present the labour costs seem to be slightly lower than in the Sassuolo area.

*3.5. Production costs in the four countries*

As emerged from the previous analysis, the four countries produce mixes of products which are quite different: this makes it extremely difficult to compare production. Nevertheless, on the basis of available data taken from previous surveys and from our direct interviews with firms, we might introduce some comments on the cost structure of ceramic tile production with regard to direct and indirect costs.

The cost structure of direct costs does not greatly differ in the four countries: by and large, this is a sector in which labour cost is 40 to 50% of the direct cost, while electrical and thermal energy account for 12 to 18% of the direct cost.

In absolute terms, production cost in Spain is lower than in Italy because of lower labour costs (and with no great differences in terms of labour productivity, *coeteris paribus*). Even the costs of raw materials and the energy costs are lower in Spain than in Italy. With regard to raw materials, Spanish firms largely use national raw materials, whereas, since the middle of the 1980s, the Italian producers have made wide use of raw materials imported mainly from Germany, while only recently large firms have been trying to substitute imported raw materials.

With regard to energy costs, the differences we have found are partly due to the different mix of products, which allows different energy consumption per unit of output, and partly to differentials in relative prices. As far as electrical energy prices are concerned, it emerges that the four countries have much bigger differences in the average cost: if electrical energy prices (per kWh) in France are used as a benchmark, then Spain has 7%, Italy 23% and Germany more than 45% higher costs[32]. Moreover, the relative prices of buying and selling electrical energy to the electricity company are such as to encourage the Spanish ceramic tile firms to produce electrical energy internally by adopting gas fueled co-generators, far beyond their internal consumption. On the other hand, relative prices in Italy are such that the opportunity of adopting this technique is limited to bigger plants that produce only for internal consumption.

Let us now consider items of indirect costs, like maintenance and consumption materials. From our interviews with firms it emerged that these costs represent a smaller proportion of total cost in Castellón and Sassuolo, while they are greater in Germany and France. This difference is an indicator of the fact that the former benefit from economies of agglomeration: the presence of specialist suppliers of various inputs in the district allows ceramic tile firms to have lower stocks of spare parts of machines and shorter delays for external maintenance.

A final consideration regards water cost which is a negligible part of total production cost. But two points should be mentioned: water tariff and water consumption per unit of output.

Even though a detailed analysis of water tariffs is beyond the remit of this study, it is worthwhile noting that tariffs of both water supply and water cleaning vary enormously among the countries: in Germany the maximum unit cost of water (treatment included) is six times higher than in Spain and more than three times higher than in Italy. But water is a major issue for ceramic tile firms in Spain and Italy for different reasons.

With regard to Spain, the cost of water supply and water cleaning is very low, but in the area of Castellón, where the bulk of ceramic tile firms are located, water is rationed in favour of agriculture: dual use is then the critical factor. For this reason, techniques to save water in cleaning the glazing lines are starting to spread in Spain. In Italy, ceramic tile firms are not so much concerned with saving a costly or rationed input, as in reducing the extremely high cost in treating wastewater. Techniques that save water input and recycle waste (from water cleaning) are then generally adopted in Italy, where sanctions on wastewater disposal that exceed prescribed thresholds are very high.

### *3.6. Public funded research and policy measures for ceramic tile production in the four countries*

Italy, Spain, and France have several forms of public funded research in ceramic tile production.

In Italy, technical advice on materials and technologies is provided by the public service centre, Centro Ceramico, and by good links with the universities of Modena and Bologna. Moreover, in the last twenty years, the regional development agency (ERVET) has sponsored many projects on

[32]Data are taken from a survey on Eurostat data and on data from the International Union of Electric Power Producers and Distribution prepared by the Spanish association of electricity companies (UNESA) in 1995.

innovation technologies in ceramic tile production, like energy saving projects, environmental policies monitoring (ISTRICE, 1990), up to the latest one: an electronic catalogue of ceramic tile and other flooring materials to be used by retailers (DEA).

In Spain, the public institution IMPIVA (Istituto de la Mediana y Pequena Industria Valenciana) founded in 1984 the research association for the ceramic tile industry, AICE, partially funded by private firms. The areas of research are the following: technical assistance, laboratory tests, quality certification, staff training and environmental problems, with regard both to the transition to the European legislation on the environment and to the technical solutions to be adopted.

In France, public aid mainly concerns R&D (CSTB, national research centre on construction materials) and training (Institut Français de Céramique, IFC). In addition, the French ceramics industry is financing its own technology and research centre, the Société Française de Céramique. All of these organisations are working for the ceramics industry as a whole, where the ceramic tile sector plays a minor role, due to its limited economic weight. Finally, a number of regional incentives are available for the implementation of new factories, most in the form of a reduction of fiscal charges.

The tile industry in Germany does not have any publicly funded technical, research or training centres, but ceramic tile firms in Eastern Germany may benefit from fiscal advantages and investment incentives.

### *3.7. Concluding remarks*

The structure of the ceramic tile industry in the four countries presents two main characteristics.

The first is the location of the industry. In Germany and France ceramic tile firms are scattered all over the country in locations generally close to raw material sources. Conversely, in Italy and Spain ceramic tile firms are agglomerated within industrial districts, where auxiliary services have been developed, and benefit from publicly funded research specifically devoted to ceramic tile production. In the past, in particular in Italy, the advantages of agglomeration were mainly due to the interaction between ceramic tile firms and machine producers that made possible a very high rate of technical change. The development of this auxiliary industry has created a dependence of the other countries on the supply of technologies from Italy. Moreover, in German and French firms we have found a higher proportion of indirect costs, due to their distance from the Sassuolo district, that requires them to have internal maintenance teams and larger stocks of spare parts of machines and consumption materials. But they also depend on the district for new design and other inputs like glazes.

The second characteristic is the increasing concentration of the overall size of the firms. Whereas in Germany and France the presence of large firms in this industry is to some extent the result of the long term growth of particular firms, in Italy and Spain, individual firms very often still remain of modest size in terms of employees and output, but in the past fifteen years there has been a tendency to create groups of companies. From a purely technical point of view, the minimum efficient size of a ceramic tile firm is relatively low, but the advantages of groups of companies are in terms of economies of overall size: a complete range of different types of ceramic tiles; the development of new products; easier opportunities of opening new markets. In all the four countries, ceramic tile firms are different with respect to core capabilities, internal structures and strategies: and these interfirm differences are relevant in interpreting the growth of this industry in the four countries.

## 4. THE PRODUCERS OF PRODUCTION TECHNOLOGIES AND THE PRODUCERS OF POLLUTION ABATEMENT TECHNOLOGIES

Even though in Spain several firms have sprung up in this sector, the core of the world production of machines and end of pipe technologies for ceramic tile production is the Sassuolo district. Firms in the district are also strong competitors of the German firms that now produce mostly for the home market.

### *4.1. The interrelationships between machine producers and ceramic tile firms in the Sassuolo district*

The enormous increase in the production of ceramic tiles in the Sassuolo district over the last thirty years has brought about a proliferation of firms which produce machines for this industry. In Italy in 1994 there were 198 machine producers for the ceramics industry, mostly located in the Sassuolo district, with a total turnover of almost 3000 milliard lire and a percentage of exports equal to 40% of sales. These firms have recourse to a network of mechanical and electro-mechanical subsuppliers present in the ceramics district[33] and more generally in the central area of the Emilia Romagna region. In this region, the existing local production system[34] of mechanical firms constitutes an important technological and productive resource for a variety of machine producers specialising in various sectors such as packaging, agricultural machinery or wood working machines.[35]

In the 1960s, within the ceramic tile district, there were basically a few, small metalwork companies which produced equipment used by ceramic tiles firms to mechanise the transfer of tiles between the various phases of the production process. The few larger firms producing machines were located outside the district, but within the Emilia Romagna region. In the 1970s several firms emerged within the district specialising in producing kilns (first tunnel kilns and then fast firing kilns), serigraphic machines, machines for glazing lines and for tile sorting and grading. Moreover, a couple of other producers outside the district became very active in supplying technologies specific to ceramic tile production.

The firms producing machines within the district have always enjoyed a continuous information exchange with the ceramic tile firms and, in the 1960s and 1970s, the ceramics firms used these machine producers as a kind of research and development department which, though external to the company, was in daily contact with the technical problems which gradually emerged during the production process. Once a particular technical solution had been found, this was offered via the machine producers to all the other firms in the ceramics industry, thus giving rise to a process whereby the innovations were distributed so efficiently that by the end of the 1970s, the mechanisation of many of the phases of moving material within the factory was already widespread inside the ceramics firms located in the district. The interrelations between producers of machines for the ceramics industry and ceramics firms themselves have made possible a high level of technical change in a sector, that of the ceramic tile, in which the firms do not carry out their own internal R&D programmes.[36] And this high rate of technical change has enabled Italian ceramic tile firms to achieve a position of world leadership both for the excellence of the quality of the products and for the supply of new products.

In the 1980s the most important innovations produced by the machine producers were to do with the introduction of microprocessors in production line machinery (mills, presses, kilns, glazing, the selection of materials), as well as in all of the transportation equipment. Apart from completing the mechanisation process of the various phases of production, techniques relating to single firing production were more widely distributed enabling firms to offer at lower prices a new product with improved technical features which extended the market for ceramics products. Finally, the

[33]Often such relationships are based on family or joint ownership connections. It should be noted that, even though this kind of arrangement is considered typical of industrial districts (cf. Brusco, 1989, Capecchi, 1990, Dei 1994), it is quite rare in the case of the interrelationships between the ceramic tile firms and the machine producers.
[34]For the notion of local production systems adopted here see Brusco (1990) and Bellandi (1994).
[35]Cf. Brusco (1989), Capecchi (1990).
[36]Cf. Russo (1985).

heavy pressures from local authorities and trade unions made it necessary to develop and introduce technologies for dealing with pollution and environmentally harmful emissions. As is the case for many technologies used in the ceramic tile production process, here too it was necessary to adapt technologies used in other sectors to the ceramics industry. This has often created original solutions to specific technical problems which were posed by the transfer of each particular technology.

It was during the 1980s, that leading firms in this sector reorganised their internal structure by increasing the subcontracting of components, and even of the entire machine, and increasing their internal research and development activity. Moreover, some of these firms started research projects with university centres, both within the region and at national level. In this way, the range of technical competencies, the technical solutions that might emerge and the opportunities of alternative uses for their machines were greatly widened and became less dependent (as they were in the past) on the interrelationships with the ceramic tile firms of the Sassuolo district.

In general, the relations between machine producers and ceramic tile producers have changed over the last ten years. Until the beginning of the 1980s, the presence of machine producers within the district gave Italian ceramic tile firms a competitive edge over their foreign rivals. This was not only due to a technical advantage in terms of the rate of innovation, but also because Italian ceramic tile firms were able to procure machines, services and know-how on favourable terms. This condition no longer persisted when, during the 1980s, the Italian machine producers began to export to Europe, Latin America and Asia, often opening workshops abroad to give technical support to their clients. As a result, foreign ceramic tile producers became more competitive. In particular, as was the case of the Spanish ceramic tile firms, access to the technologies until then used exclusively by Italian producers was an important factor in enabling them to establish themselves on the European market. The emergence of stronger competitors marks a turning point in the relations between the Italian machine producers and the ceramics firms in the Sassuolo district. In fact, the machine producers operating abroad found the export markets more advantageous precisely because they were able to fix prices.

The increase in exports of machines for the ceramic tile industry has also given impetus to the rise of the new market for complete plants: 95% of the world plant market is covered by the Italian firms Sacmi, Siti, Nassetti and Welko. These four large size firms (with a turnover of more than 50 milliard lire in 1994) are market leaders both in terms of their ability to generate technical innovations as well as in their commitment to opening up new markets (cf. table 3).

All of them are located outside the Sassuolo district. This is largely explained by the historical background of these firms and by the fact that, even though the local producers of the district are excellent producers of single machines, they have not had great success in the plant sector: the ceramic tile plant is extremely complex and relies on specialised skills which draw on widely varying technologies. The plant producers plan the design of the whole plant according to the particular needs of the client and co-ordinate the production of the individual machines. Such production may be integrated to different degrees within the firm.

In general, the entry of new firms into the ceramics mechanical plant sector is extremely rare. The four biggest producers were first producing specific machines and only in the 1980s started selling complete plants[37].

In particular, the organisational structures of the four ceramics plant market leaders are quite different. Sacmi has its head office at Imola and uses subsuppliers, predominantly in the Sassuolo area, that do not work for its competitors; it also imposes on them prices at which they can sell their product to the end market. Siti has its head office at Novara and has several subsuppliers in the Sassuolo area, but also in Lombardy; the subsuppliers are not required to sell exclusively to Siti. Nassetti has its head-office in Milan and relies on subsuppliers in the Sassuolo area; it gener-

[37]Though the world market in the ceramics plant sector is in rapid expansion, all of the plant firms are trying to produce technologies for the bathroom sector where a higher growth rate is predicted, even if the processes of moulding, firing and transporting are still difficult to standardize because the variety of forms for each series of bathroom suite requires a particular kind of modeling and involves internal transport techniques which are not yet very automated. The only foreign competitors are the German ceramics plant producers who now exclusively produce plant for bathroom suites; this is the case of Dorst, which from the Fifties had already been an important producer of presses, but which now produces very little for the ceramic tile sector.

ally has a shareholding in its subsuppliers. Welko has its head-office in Milan and several factories in Sassuolo; all work is carried out internally and it buys in only standardised components. All these firms have significant internal research and development activity, and, in the case of Sacmi, this is partly linked to some joint projects together with public research centres in Italy.

Apart from these four plant producers, the only other companies operating in this sector, with a marginal position, are Mori and Ipeg. Both have previous experience in kiln production and have recently moved into the plant sector. They are highly skilled in the planning stage and have total recourse to subcontractors for the production of the various machines that make up the complete plant.

As shown in table 3, the four biggest plant producers account, directly or indirectly, for 30% of the total employment of the whole machine production sector, and have a share of 44% of its total turnover.

In general, the growth of machine producing firms has taken place within the Sassuolo district. This has also been the case with the biggest producers located outside the district, who have increased their production within the district either directly, by opening new establishments, or indirectly, by increasing the volume of output subcontracted to firms of the district.

It should be noted that hitherto in Italy policy measures to stimulate delocation of production have not worked. Public incentives for new investments in the South of Italy were not effective because, in the case of machine producers, the necessary pre-conditions for production processes based on mechanical expertise are not strong enough to stimulate the growth of ceramics machine firms organised like those in the Sassuolo area. However, a limited delocation has taken place towards an albeit small ceramics development pole in the Modenese lowlands, at a distance of forty kilometers to the North of Sassuolo. However, there does not appear to be a critical mass sufficient to create an alternative pole of services in that area.[38]

It is worthwhile noting that even an operation such as die maintenance, which is one of the maintenance activities regularly carried out as a function of normal wear and tear, does not seem able to locate near the ceramics firms even abroad. It is sufficient to recall that in 1994 the turnover from sales of presses abroad was 240 milliard lire and that for the maintenance of presses abroad the turnover was 130 milliard lire. Neither has Germany seen the development of die maintenance activity which continues to be carried out in Sassuolo. In Spain, too, a big market for Italian machine producers, non-routine maintenance is entrusted to the Italian producers who supplied the plant.

The critical mass, the way of working, the convenience of having personnel on hand who instantly understand the nature of the problem is what continues to have a decisive influence on the location of machine producers in the district. For these machine producers, in fact, what matters is a dual contact: that with ceramic tile firms – the users of their machines – and that with the mechanical and electro-mechanical firms supplying them with particular components and intermediate processes. However, the economic importance of that dual contact cannot be interpreted only in terms of lower transaction cost, but should also be considered in the social and institutional environment in which those interrelationships take place.

### *4.2. The Italian producers of emission abatement technologies*

Italian firms producing pollution abatement devices for ceramic tile production are located in the Sassuolo district. As shown in table 4, in 1994 total estimated turnover of the firms producing abatement devices and offering related services was about 100 milliard lire. These firms sell mainly in the home market, even though some devices are sold abroad either directly or indirectly through the bigger firms selling complete plants. Total estimated employment is 345 workers.

[38]It should be noted that transport costs are not such as to encourage a growth of machine producers outside the territory of the industrial district. For example in the case of sales directed to China, a country where it is predicted that there will be a heavy expansion in demand for ceramic tile plants in the coming years, the cost of sea transport, based on the Cif rates, has only a 5-6% impact on the total cost of the plant. In such a case, provided that no import barriers are set up, it is not economical to produce in China. Also, at present, the demand for plants comes from the South of this country. In the future, for any export to the North of the country the transport costs would be the same as those from Italy.

In the mid-Seventies, the demand for pollution abatement technologies for the production of ceramic tiles was met by firms which were already producing such devices for other sectors: firms like Hascon, Decardenas (which now does only engineering development), Pibody Italia (the subsidiary of an American company) had expertise in the field of emissions from steelworks and used sleeve filters as well as cyclone filters. They supplied ceramic tile firms with sleeve filters which had been adapted to the particular emissions of the tile industry, and they had success. To meet the increasing demand on the part of tile manufacturers in the ceramics district, these companies began to subcontract work to mechanical engineering firms located in the district. Quite soon some of these engineering firms were able to design entire abatement devices and to enter into competition with the companies who had been their commissioning clients in the first instance and who were now swept off the board by companies within the district. These were firms which gradually mastered the design and production features of plant that had a relatively simple technology behind them. In addition the firms in the district enjoyed the undoubted advantage of their proximity to ceramics companies which made it possible for them to formulate solutions which were most suitable to the particular problems which had emerged in the phase of the plant's installation and fine tuning. Then, as now, though we are not talking about complex technology, the devices for the abatement of airborne emissions are produced with one or two standard components (filters, ventilators) which are customised in the specific project relative to the production plant in which it will be installed. The need to design the abatement device for each single production unit derives from the non-standard form of those units which differ in terms of the technical characteristics of the machines, the way they are set up within the factory and the prime materials they use.

There are 10 firms which operate in this sector and, as in the case of machine producers, they resort to subcontractors, 20 other small firms that are generally bound to contractors by informal though strong links. The main producers are Eurofilter, Cami, Cefla.

Apart from firms which produce devices for pollution abatement, the combination of environmental pressures has led to the formation of firms which carry out chemical analyses on air, water and soil and physical analysis for noise and ionising radiation; also machine testing, waste site reclamation and environmental consultancy of various kinds. This concerns about 10 companies with less than ten employees each which have sprung up in the last fifteen years in the ceramics district and, in general, are independent of firms producing environmental technologies and the ceramics firms themselves. Some of these firms have expanded their activity in concomitance with the application of particular controls provided for under recent environmental legislation, as for example is the case with the application of the legislative decree 277 of 15 August 1991 which requires all firms with at least one employee to carry out internal noise checks and to ensure such checks are repeated at regular intervals depending on the type of emission.

### *4.3. The producers of production technologies and producers of pollution abatement technologies in Spain and Germany*

Both Spain and Germany produce production technologies and pollution abatement technologies for the ceramic tile industry.

With regard to Spain, in Castellón are located several branches of the Italian leaders in the production of the core technology (spray-dryers, presses and kilns). Some of these branches work in association with local firms. Through these interrelationships, the ceramic tile firms in the Castellón district have had the opportunity of being much closer to the process of development and adoption of new technologies than for example German and French ceramic tile firms.

In the last decade, the growth of the ceramic tile industry in Spain has stimulated the growth of several firms, besides the Italian machine producers, producing machines or providing auxiliary services for the ceramic tile firms. In the Castellón province there are 50 local firms which produce moulds, glazing lines, serigraphic devices, thermal and noise insulation devices and filters. Some other firms are distributors of glazes produced by multinational companies or specialise in equipment installation and maintenance.

Even though firms are quite small (only a dozen employ more than 30 workers and the biggest one – a mould producer – employs about 80 workers), some local firms are quite active in technology development, especially in glazing and decorating techniques. Spanish producers of machines for the tile industry are now exporting 10-15% of their output, although the present high level of internal demand does not stimulate selling abroad.

The number of firms supplying abatement systems and equipment scarcely exceeds the dozen. Most of these are based inside the ceramics district with the exception of a few firms in Catalonia and the Province of Valencia. The majority are not exclusively suppliers to the ceramics sector (besides filter suppliers, there are suppliers of transfer pumps, measuring instruments, etc.). Over and above these firms, there are firms (building, plumbing, etc.) who install emission collection, conduction and abatement systems. Firms specialising in environmental auditing are based in Madrid and generally take part in the projects for installing abatement devices in ceramic tile firms.

In the future, the growth of the ceramic tile industry in Spain will almost certainly be accompanied by an increase in the auxiliary activities already present in the area of Castellón.

In Germany the several producers which were originally world leaders in the production of machines for the ceramic tile industry, now play a minor role in this sector, which sees the leadership of Italian manufacturers of these technologies. With regard to pollution abatement technologies, while waste water cleaning devices are designed and planned by the ceramic tile firms themselves and installed by construction firms, all noise, dust and fluorine control devices are bought from specialists producers. They offer devices for a wide range of pollutants and flow capacities.

German manufacturers of pollution abatement technologies adopted in ceramic tile production are generally medium size companies (70 to 300 employees) and have developed their technology for the metallurgical, cement or heavy ceramics (bricks, roof tiles, etc.) industry, but never specifically for tile production. As a consequence, fine ceramics (tiles, tableware and bathroom suits) account only for about 5% in their turnover.

### *4.4. Concluding remarks*

The mechanical firms of the Italian Sassuolo district have a crucial role in enhancing a general process of innovation and then in the process of quantitative and qualitative development of the tile industry at world level. The location of the machine producers within the district is largely explainable in terms of the history of the development of this activity in response to the increasing demand for machines within the district and in terms of the more general advantages they now derive from recurrent relationships not only with their clients, but also with their suppliers, which are located in the district and in the central area of Emilia Romagna. These advantages are such that even the biggest producers located outside the district, who could resort to subcontractors located in other areas with significant agglomerations of metalworking firms (like Lombardy or Piedmont), are trying to increase their presence within the district.

The case we are considering cannot be schematised in terms of an industrial structure with several leading firms, their network of subcontractors, and other small marginal producers. Here we have a production system in which the recurrent interrelationships between firms are not only based on the exchange of goods and services, but also on an inter-firm, multilevel, cross-fertilization of ideas. All this provides locational advantages in terms of lower transaction cost.

However, the analytical benchmark in considering the trends in the development of these firms is not so much a transaction cost model, as one that focuses on the inter-firm relationships within the production system. What we want to highlight here is that these interactions lead to an overall return which is higher than we might have supposed if the firms were merely aggregated on the basis of their individual physical capitals and of their technical and organisational competencies.[39] The overall return we want to highlight here is not so much the global physical output realised within the production system. It rather refers to the innovative output that might be generated by the system. In this perspective we are particularly interested in considering to what extent this production system would be able to shift ceramic tile technology towards a new technological trajectory characterised by trade-offs between output increase, reduction in polluting emissions and competitiveness (this point might be explicitly stated in terms of reduction, or zero increase, of production costs for ceramic tile producers). This shift would require the involvement of several and various technologies that draw to different degrees on knowledge which is both codified and

[39]This consideration is based on the analysis of the systemic nature of industrial district. Cf. Becattini (1990).

tacit. Moreover, this shift would also require technical and organisational capabilities that are not available to every firm in this production system. Indeed, only a few bigger firms maintain internal research and development activities and interrelationships with public research centres. However, these firms also have networks of interrelationships with other firms in the sector. These interrelationships would make possible the all-important development stage, necessary to initiate the shift towards the new trajectory, and might generate feed-back between development of prototypes and applied research. Moreover, a new trajectory would probably entail modifications of the various core technologies adopted in the production of ceramic tiles (firing and glazing) and this might, in turn, imply a change in the characteristics of the machines and plants being produced.

This final point is critical when one considers the development of a new technological trajectory. It highlights the fact that the firms operating in this sector and involved in a common production system might, by virtue of their different and various technical and organisational capabilities, be able to pursue future initiatives along a trajectory more compatible with the environment.

However, here uncertainty plays a crucial role. In fact, even if there were the technical and organisational capabilities to shift toward this new trajectory, these technical opportunities might not be a sufficient condition to stimulate change. New technologies would in fact be accompanied by investment decisions in research and development in the firms producing production technologies, but they would also imply investment decisions in the ceramic tile firms themselves. Uncertainty about future developments of a clean technology might be reduced if, as a result of an institutional constraint, firms were compelled to adopt a clean technology. In this case, the joint action of a stimulus on demand for new capital goods and the presence of technical and organisational capabilities might focus innovative activity in the direction of the required changes.

## 5. ENVIRONMENTAL PRESSURES, ENVIRONMENTAL POLICY AND PERFORMANCES IN THE FOUR COUNTRIES

### *5.1. Environmental policy*

#### *5.1.1. Italy*

The measures used as institutional tools are national laws and several regional laws that make the content of national standards more precise. Moreover, the regional level is that of the territorial plans that co-ordinate all environmental matters.

In Italy, environmental problems generated by ceramic tile production emerged at the end of the 1960s when in the space of few years tens of new ceramic tile firms opened in the Sassuolo district. During the 1970s, under the pressure of trade unions, a general awareness of the negative effects of ceramic tile production technologies on population health emerged. In the same period, general prescriptions on pollution started to be applied.

Italian environmental legislation started in 1966 with a law on air emissions that remained inapplicable until dispositions were formulated in 1971[40] However, the law was applicable only to those areas for which the local administrative authority required the application. Starting with Sassuolo in 1972, in the next few years other Comuni required the application of the law on emissions in their territory (Scandiano, Casalgrande, Fiorano and Maranello in 1973, Castellarano in 1974, Formigine and Rubiera in 1976, Castelvetro in 1979 and, finally, Viano in 1981). The core of the ceramic tile district, i.e. the Comuni of Sassuolo, Fiorano, Maranello (in the province of Modena) and Scandiano and Casalgrande (in the province of Reggio Emilia) thus became subject to environmental controls.

A key figure in directing general attention towards environmental issues has been the trade union of ceramic tile workers at provincial level (Fulc). They considered in tandem the working conditions internal to the work place and the external environmental state affecting the living conditions of the population. Moreover, an important role has been played by the interactions between firms and Comuni authorities: broadly speaking, this spirit of co-operation and collaboration has produced a better environment and more competitive conditions for the firms. Also, this collaboration has made it possible to find the technical solutions to the specific environmental problems related to tile production.

During the 1960s, environmental pressures emerged internal to the ceramic tile firms. Working conditions were recognised as being very unhealthy. In 1970, results of several pieces of research on the health of the population living in the ceramic tile district were discussed during a Conference held in Sassuolo by the local administrative and health authorities: the main conclusion was that at every stage of the production process there were problems related to great quantities of powder dispersed in the air, noise in excess of prescribed limits and an unhealthy microclimate. The rate of abortion was higher than the national average and saturnism (lead poisoning) was a critical disease: it has been estimated that during the 1970s, 30% of workers employed in ceramic tile firms were exposed to the risk of saturnism: Sassuolo was the biggest Italian area with this risk (see Collini *et al.*, paper presented at the Conference held in Sassuolo, 1970).

Once the bad working conditions had been recognised an increasing awareness developed of the need to monitor the external effect of pollution caused by ceramic tile production. In fact, some pollutants – like boron, fluorine, zinc, manganese, chrome present in the air or in water emissions from ceramic production – started to affect the health of the population living in the area (e.g. a study on a sample of children showed critical levels of the rate of hematic lead).

When environmental problems were considered, it immediately emerged that there was no standard to which to refer emissions, or toxicity of residuals, specific to tile production. This is why during the 1970s, and for boron treatment even the 1980s, the services of Medicina Preventiva del Lavoro (preventive workplace medicine) started research on ceramic tile production that generated a substantial body of specific knowledge that was incorporated in threshold values.

[40]Cf. the law n. 615/1966 on air emission and the Decree of the President of the Republic (DPR) n. 322/1971.

In 1970, regions were defined as administrative units and among their duties were environmental controls. When at the beginning of the 1970s the *Comitato regionale inquinamento atmosferico dell'Emilia Romagna*, CRIAER, started its activity there were no general thresholds to be adopted for ceramic tile production and CRIAER dealt with hundreds of separate cases before managing to define the specific thresholds in 1974. Threshold limits for gaseous and water emissions in Emilia Romagna and in Italy are listed in table 5 (columns 2, 3, 7).

Common services were set up by ceramic tile firms and local administrations (Comuni and Provincie) in order to monitor air conditions, and data were analysed by the local health authority. During the 1980s, they adopted biological water monitoring and air monitoring.

National regulations applied with regard to toxic waste disposal concern the storage and transport conditions that must be authorized by the local authority.

With regard to noise, national legislation has effectively brought noise within the factory under control and in the case of abuse applies heavy sanctions. However, apart from noise generated by mobile sources, the many devices (generally all the air and water treatment machines) are external to the factory walls and these sources are regulated by the present legislation which is in its implementation phase. By the terms of the Ministerial Decree of 1991, local authorities are required to define the zones within their territory where different day/night limits set by the law apply. But at present no local authority has yet defined them. The main obstacle to setting these zones is that in many cases in order to reduce noise under the prescribed level it would be necessary to reorganise road-links and transport. The planning decisions involved, the large amount of investment required, and the necessity of new skills to evaluate and intervene on noise make this issue a long term one.

In 1980s the following division of tasks was defined at regional level: the Presidio Multizonale di Prevenzione, PMP, makes "fiscal" controls on behalf and on request of CRIAER and trade unions; the Servizio di Igiene Pubblica, SIP, carries out checks (at least once a year) on firms' registers and abatement device instruments. In particular, technicians from the Servizio di Igiene Pubblica perform the following tasks: inspection of production plants, checks on the existence of authorization for production, checks on the proper and continuous working of the abatement devices; monitors that self-checks are carried out in accordance with defined times and procedures; monitors that output of internal inspections is correctly registered. The Comuni receive all the reports drawn up by the SIP and PMP related to firms in their territory. On the basis of the reports, they may either file the report if any default is recorded, or send a letter to these firms not complying with the norms, or request PMP to take samples.

The Emilia Romagna Region delegated all the inspection activity and the assigning of authorizations (for gaseous emissions) to the provinces. This has created an efficient division of labour between the regional and the provincial level: the regional committee working only on the definition of the specific thresholds for emissions of different production activities.

Since 1993, as a result of the Referendum on environmental controls, environmental issues are no longer under the control of the Health Department at national and local level. In 1994, the Emilia Romagna region has instituted a regional Agency (Agenzia regionale prevenzione ambientale, ARPA) that co-ordinates all the environmental measures. Employees previously employed by the PMP and SIP making environmental controls, and employees of the regional administration and the provincial administrations involved in the environmental controls, now work under the aegis of ARPA.

Given the above picture of environmental pressures, regulation and enforcement, the efficiency of measures adopted up to now is widely recognised: not only has the internal working environment been considerably improved, but emissions are under control and residuals are largely reused in the production process. With regard to boron pollution, which during the 1980's emerged as a serious problem to tackle, technical solutions for treating water emissions are now available and widely applied. These specific solutions were found as a result of a joint research effort on the part of ceramic tile firms, machine producers and publicly funded technical research centres.

Even though the need for continuous controls of the environmental effects of tile production still remains, a new emerging problem is attracting public attention: the effects of pollution due to the transport of raw materials, intermediate goods and end products of the ceramic tile district. As is well known, polluting emissions from mobile sources are very difficult to monitor and reduce, but the effects in the district are now dramatic.

A recent project financed by the EU in the framework of the Thermie project (DEMETRA, Demonstration of the Energy Methods Effectiveness in Transportation) has estimated the impact, within the district, of the present pollution due to related ceramic tile production is transport. The impact from CO2 emissions due to transport within the district is estimated to be 20 times greater than the emissions of CO2 due to ceramic tile production in the district. Moreover, congestion and noise due to traffic are very intense.

It should be noted that a high proportion of the vehicles operating for the production of ceramic tiles move around within the district: we know from the DEMETRA project that two thirds of the vehicles do not pass the perimeters of the district. The reason for this huge number of trips internal to the district is twofold. First of all, the size of individual batches sold is generally lower than the vehicle's loading capacity; second, sales from ceramic tile firms are CIF and transport is organised by the retailers, who are not directly involved in the organisational problems arising within the district.[41] Given these conditions, several trips within the district are necessary before a lorry's load is complete for the final destination.

The DEMETRA project has further suggested three kinds of measures. The first regards the implementation of road transportation infrastructure within the district and better linking of the district to the main roads; the second regards railway services with the experimentation of new wagons to be used both for raw materials and end product transport; the third measure highlights the need for changes in transport methods within the district, by forming new "transit points" to collect small orders.

Finally, of less impact than transport, the use of organic substances is generating an increasing public concern: public complaints about the unpleasant smell. Technical solutions are now under investigation. They regard both the replacement of these substances with other solvents (here firms producing colours are involved), and pollution abatement technologies.

To sum up: the critical environmental factor for the district is the high density of firms, each of them polluting below the defined stringent threshold for water and air emissions, but all of them producing a negative effect at local level within the district. The source of pollution are emissions from individual firms and from transport related to ceramic tile production. The ceramic district is part of a wider area declared as being at high environmental risk because of the natural characteristics of the geographical area (conoids of the river Secchia) and for the high density of population. This is why a negative environmental impact within the district may alter in a significant way a wider area surrounding it. For these reasons, as a result of collaborative efforts between public administration and private ceramic tile firms, a new agreement on the environment is now under discussion: each firm will respect the present limits of its emissions even in the case of increased output. Attention is then shifted to the global amount of pollutants tolerable in that area. This implies a strong move towards innovation in both production and pollution abatement technologies. However, in all events, significant organisational changes are urgent because of the environmental impact of transport within the area.

*5.1.2. Spain*

General regulations on environment protection in Spain are issued at national level, while regions are empowered to develop and enforce those regulations. Regions are also empowered to set up extra regulation to further improve environment protection.

In general, environmental regulation relies on monitoring quality standards of air and water at the input stage and the way toxic or dangerous wastes are treated. Authorities are empowered to set up emission limits, to make it compulsory to install specific devices or to revoke a firm's license to carry out activities, if necessary.

With regard to environmental impact factors related to ceramic tile production, there is no specific legislation, either national or regional.

As far as gaseous emissions are concerned, the limits are on dust emissions and, only in the case of the production of frits, there is a limit on fluorine emissions. If oil products were used as

[41]Cf. Russo (1989) for a detailed analysis of the economic aspects of the transport within the industrial district.

fuel, there would be limits on SO2 and CO emissions (see table 5, column 4). It should be noted that the Decree 833/1975, which establishes the gaseous emissions limits, expresses the limits on air emissions in terms of physical conditions different from those considered by the legislation in force in Italy, Germany and France. In particular, being defined at a lower temperature, the Spanish Nm3 contains a mass of air and pollutants about 10% greater than the Nm3 used in the other legislations.

There is a limit for a number of pollutants contained in waste water emissions; these limits, set up at national level, are rather permissive (see National Act 29/1985 and derived regulations, and Regional Act 2/1992 and derived regulations). River Basin Authorities (*Confederaciones Hidrograficás*) are empowered to set up more restrictive limits on emissions in order to guarantee the required water quality levels to the water used downstream. The basic framework to do this is a water planning policy, but political disagreements among regions on the criteria for the planning and management of water have been blocking the progress of both national and basin hydrogeological Plans. Therefore, limits in force are those shown in table 5 (column 8 ).

Since the middle of the 1980s, lower limits, the same as those contained in the Italian legislation, are adopted to calculate the tax on water discharge paid to River Basin Authorities. But hitherto this tax has not been applied properly because of non-registered water discharge and inefficiencies in the control of quality and quantity of discharges. The Regional Government of Valencia applies a specific tax to pay for the cost of purifying waste water. The quality of water discharge, the quantity of water lost in the production process of the different industrial activities, or the quantity of water resulting from raw materials are to be considered by means of applying coefficients. The tax has been on the statute book since 1993, but the coefficients have not yet been set. The deadline for firms to declare the characteristics of water discharges ended by mid-1995. In the last few years, the Regional Government of Valencia has stepped up its activity to estimate the characteristics of water discharge from different industrial activities and the feasibility of firms having access to their own water sources (wells) in the different areas of the region. The pursue of these preliminary studies is to establish a benchmark to check the consistency of the information provided by the firms.

At present, there is no regulation on quality standards for irrigation water and there is no systematic definition on water uses. All these questions await the passing of the "Plan Hidrogeologico". This lack of general regulation means that, for some pollutants, limits on emissions are less restrictive than they were in the past, because the *Confederaciones Hidrograficás* set up particular limits for each river. This is why for the Mijares river in the Valencia region particular limits were set: its water is in fact used for irrigation and part of the watercourse was even preserved for domestic use when purifying techniques were still not common. The pollution comes, in the final part of its course, mainly from urban waste water and the agricultural sector.

Activities considered a nuisance, unhealthy, harmful or dangerous (*actividades calificadas)* are regulated by the National Decree 2441/61 and the Regional Act 3/89. This legislation defines a list of activities that require a special authorization. Municipalities and Regional governments are empowered by means of this Act to carry out global controls of the environmental performances of companies working in these activities to enforce all environmental legislation.

There are no limits for other wastes not disposed of by means of a free flowing fluid. The legislation defines a list of activities and production processes that are potential producers of toxic or dangerous wastes and regulates the way that they may be disposed of. Some registering and recording procedures are required of companies working in those activities concerning waste production, transportation and waste management.

*5.1.3. Germany*

Historically, the first pieces of environmental, health and security legislation appeared during the 1920's and 1930's, following pressure from work councils and the growing awareness of the silicosis risk (due to dust). Also in those years, protection measures on machines (e.g., presses) were installed. In the seventies the environmental impact of air emissions became an important public concern, and it was notably the pressure from green groups that lead to one of the most restrictive legislations for air emissions.

Today, environmental regulations concerning the ceramic tile industries in Germany, but also in France, are pieces of national legislation which affect most sectors of industry. They have not been designed specifically for the ceramic tile industry. Neither are there regional or local standards, as in Italy. Clearly, the reason is that ceramic tile firms are not concentrated geographically in those countries, thus they do not generate the same important environmental impacts as in Italy or Spain and consequently are not exposed to strong pressure from the local population and authorities.

Environmental regulation concerning the ceramic tile industry in Germany is described in the Umweltschutzgesetz (UmwG), the Bundesimmisionsschutzgesetz, the Wasserhaushalts-gesetz, the TA-Luft and the Bundesimmissionsschutzverordnung (4. BImschV. and Anhang 17.). Table 5, column 5, contains the air and water emission thresholds.

Regulations are enforced by local authorities (Gewerbeaufsichtsämter). They require depollution certificates which can be issued by authorized companies (e.g., TÜV). This means that the firms have to prove regularly (every 6 months to 3 years depending on the installation) that their process conforms with the regulation.

*5.1.4. France*

The maximum concentration values for all sorts of industrial emissions (air, water, waste, noise etc.) have been defined in a decree of 1 March 1993. This regulation concerns the whole of French industry and applies only for flow masses much higher than the typical flow mass of a ceramic tile factory (see column 6 in table 5). Thus, many of the concentration values in table 5 do not have to be applied by ceramic tile firms, as is the case for fluorine.

The DRIREs (Direction Régionale de l'Industrie, de la Recherche et de l'Environnement) are responsible for the enforcement of regulations. They belong to regional authorities and may request depollution certificates in cases where they suspect firms of exceeding threshold limits. Therefore, the application of emission standards can vary greatly from one region to another, because the DRIREs are not obliged to request depollution certificates. As in Germany, certificates are issued by authorized, independent laboratories.

*5.2. Environmental performances*

*5.2.1. Italy*

A recent survey conducted by the Public Health Service of Sassuolo and the Italian Ceramic Centre of Bologna[42] reports the results from a comparative study of the environmental performances in the ceramic tile industry. Three sets of data are very interesting. The first regards the specific flow rates of the gaseous emissions from kilns within the Sassuolo district in the period 1980-1992: both for single and second firing, these flow rates ara now lower and with a smaller range. In particular, for single firing they went down from 6-11 to 3-3.5 Nm3/kg and for second firing the reduction was from 6-7 to 2. The second comparison regards output, energy consumption and CO2 emissions in the Italian ceramic tile industry: in the period 1980-1992, output increased by 28,6%, while both natural gas consumption and CO2 emissions decreased by one third. The latter set of figures refers to overall water consumption within the district which is, on average, half of the overall requirement (presuming there were no recycling). Thus, it might be concluded that air and water treatment technologies have been widely adopted and the monitoring of environmental performances of firms is effective. But we should not forget that a major explanation of this performance is due to the changed composition of output in the past 15 years: by and large one firing production is cleaner than two firing production.

Performances in the disposal of residuals is also impressive: a very high proportion of recycling and disposal in controlled sites. In particular, sludges from treatment are disposed of in the following proportions[43]: 58% is recycled into wet preparation of raw materials, 4% in frits preparation, 1% into enamels preparation carried out inside the firm, while 36% is handed over to a centre spe-

[42]See Busani and Timellini (1995).
[43]Data are taken from Assopiastrelle (1995).

cialising in waste disposal.[44] Also 25% of exhausted lime is recycled in raw materials preparation, while 70% is disposed of by authorized centres and 5% is stocked by ceramic tile firms.

In the past decade, there has been a wide adoption of energy saving techniques, both by using machines that have lower consumption of electrical energy per unit of output and by installing co-generators. Co-generation represents an important alternative in those cases where thermal and electrical energy are required simultaneously. Given the relative prices of buying and selling electrical energy to the electricity company, the break-even point has been calculated to assess the economic opportunity of installing a co-generator.[45] In Italy, relative prices of buying and selling tariffs are such that the already installed 16 co-generators plus the 11 that will be installed by 1996 cover all the plants that might find it worthwhile adopting co-generation.

*5.2.2. Spain*

In Spain the present national environmental legislation is fragmented and also, predictably, subject to short term changes. The Valencia Regional Government has announced its intention of incorporating European directives into the law and drawing up a Bill for the Environment. However, the fact that the measures are not fully developed explains why control of emissions at factory gates has scarcely been systematised and why measurement criteria for different parameters are heterogeneous.

From a survey carried out in 1993 by the Ceramic Technology Institute of Valencia it emerged that almost one fifth of the ceramic tile firms do not adopt emission abatement technologies and only forty per cent of firms have periodic collection of waste. In the Castellón district, 80% of sludges from air treatment are recycled, 70% of sludges from waste water treatment, 30 and 70% respectively of broken unfired and fired tiles.[46]

Firms are not obliged to carry out a systematic check on the real values of their emissions, which are subject to qualitative and quantitative changes according to types of components used for different series of products. Nevertheless, several ceramic tile firms consider it important to know the quality of their emissions in order to use these results to improve the image of the firm as one having environmental-friendly production processes.[47] Thus, very often, before carrying out a project to adopt pollution abatement technologies, emission measurements are performed (or are estimated) simply to state the non-compliance with the threshold levels required by law, while guaranteeing such compliance as the result of the project.

In order to assess the more recent tendencies of firms in the ceramics district of Castellón as regards the environment and how they are tackling the problem, 25 firms in the province of Castellón that were running environmental projects during the first six months of 1995, have been analysed. The distribution of firms under study was the following: three firms producing spray dried clays, sixteen a producing ceramic tiles, five producing frits, enamels, and colouring, one producing equipment goods. The projects mainly involved installing or improving suction systems and systems for treating air emissions, and also improving water treatment and recycling systems, while recovering waste sludge.

The results of the analysis may be summarized under the following seven headings.

First of all, one third of the firms under consideration included in their projects simultaneous actions on both gaseous and liquid effluents.

Second, most of the projects were carried out by firms of medium size (from 30 to 100 workers and between 2,000 and 6,000 m2 of daily production capacity), the majority of whom have no spray drier within the factory.[48] The majority of the projects (nine out of fifteen of which envisage water and sludge treatment) concern the installation of waste water treatment plants on glazing lines and pump cleaning. This is done with the idea of re-using the water for cleaning and transferring sludge to firms supplying spray dried clay (three projects of firms producing spray dried clay

[44]Note that authorized transport is necessary.

[45]Cf. Nassetti (1995).

[46]Data are taken from the survay carried out by the Instituto de Tecnologia Céramicas of Valencia, "Environmental situation of the ceramic flooring and tiling sector in the province of Castellón", 1993.

[47]See the results of the survey carried out in 1993 by the Instituto de Tecnologia Céramicas of Valencia.

[48]This situation is consistent not only with the structure of the sector, but also with the results of a previous survey (see note 43), according to which the larger sized firms, who generally had their own atomizer, had normally resolved the problems of treatment and recycling of gaseous and liquid emissions.

who have made their plants suitable for receiving residual sludge from their clients should be added to the above mentioned nine). Only in one case is partial reutilisation being made of residual sludge from enamelling lines as raw material for new enamels. Installing abatement systems in these cases is deemed to be a water saving formula (saving the corresponding tax paid on waste according to consumption), while facilitating transport, to the atomised clay plants. It should be noted that the abatement device allows a grater flexibility since it reduces the need to recycle all water used in the production process. In one case, the intention is to introduce a process for drying sludge produced in enamelling using hot gases; the sludge being reused as enamels and redressing.

Third, in a situation in which the law is not very specific, compliance requirements are not systematic and the abatement is costly, the decision of a firm to install a abatement device for gaseous emissions largely depends on its particular conditions, i.e., internal atmosphere, proximity to urban nuclei, or reasons related to the technical requirements of certain production processes (as in the case of clay particles escaping into enamelling lines that cause deterioration in the product because of flaws in the enamelling). This explains the lower number of projects involving gaseous effluents. In general, firms have some kind of filter system in the more problematic sections. Their efforts are generally directed towards improving the suction systems, installing filters, or channeling gases from these sections to filters in other sections.

Fourth, some projects are designed for energy saving by taking advantage of the hot gaseous emissions, such as the above mentioned idea of drying residual sludge in a spray drier, or another project which involves drying cars prior to entering the kiln, estimated to save between 8 and 10% of energy consumption in kilns. Beyond these energy saving practices, there has been, in recent years, a wide adoption of co-generation by larger firms. It should be noted that in this case a major stimulus to the adoption of this technique is the opportunity to sell the internally produced electrical energy surplus to the electric power company. Unlike in Italy, in Spain it is economically advantageous to sell energy to the electrical company, so that 39 co-generators have already been installed with a power capacity much greater than the Italian one and almost twice exceeding the internal needs of the factories in which they are installed.

Fifth, in firms producing frits, enamels, and colours the problem of emissions is greater as recycling possibilities are fewer and technically more complex. Treatment is necessary in order to allow water to be disposed of and heavy metals contained in gaseous emissions to be prevented from escaping. Five frit, enamel and colouring firms of the twenty that exist in the province of Castellón have presented projects in the first quarter of 1995 for the Industrial Plan for Improving the Environment. Among these there are medium sized, local firms (three) with a staff of between 40 and 70 workers, and two multinational firms established in Castellón. The projects generally consist of installing or improving suction systems in presses and kilns, installing filters to capture dust using a dry method, and installing waste water treatment plants that are an improvement compared to those already in use.

Sixth, there are only a few research and development projects in the area, but they should be mentioned because of the importance of the auxiliary services and the Centres for research and technical support in the ceramics sector. Out of the three projects examined, only one involves a large ceramics firm well known for quality and environmental care, and which has experience in research, having worked on a contract with the Ceramics Technology Institute. The aim of this project is to recycle throwaway wastes, reusing them in the production process. This, at present, is the only type of emission and waste which the firm involved is not recycling. One of the two remaining projects involves developing non-polluting organic base pigments. This is being done by a multinational firm manufacturing ceramic enamels and colouring at their plant in the ceramics district. The second involves developing treatment filters for gaseous effluents that attain a higher level of solid by using new reagent methods to retain emissions.

Lastly, investment in abatement technologies is relatively low (6 to 20 million Pta) if compared to total investment required to install an entirely new production plant (it may cost 800 million Pta). This implies that abatement technologies do not account by themselves for a big business volume able to fuel an important economic activity based on the production of abatement devices for the ceramic tile sector.

Abatement technologies are easily installed at low cost when this is done simultaneously to the planning and building of a new production plant. Conversely, it is extremely costly to install such devices in operating plants. This explains why recent decisions by ceramic tile firms to increase their production capacity have been accompanied by the decision to install abatement technologies to improve their environmental performance with regard to forecast future requirements. On the other hand, firms that are not increasing their production capacity tend not to install abatement devices because of the very high cost of installation.

*5.2.3. Germany*

In terms of pollution prevention, German firms have been under some pressure from local authorities and inhabitants to improve their environmental performances, because many of them are located close to residential areas. This particularly forced them to conform with very high night-time noise protection standards (ranging between 35 dBa and 45 dBa at 10 m away from the plant) and seems to be the most significant remaining environmental problem. All firms interviewed said that in general their environmental performances are below concentration values specified in the regulations.

Waste water is being cleaned and/or recycled at a rate of 50 to 85% today and firms are targeting 100% in a few years. Waste water can easily be added to the body during the preparation, the contained toxic particles becoming inert during the firing process. Sludges from waste water cleaning devices are recycled in the mass, or, in the construction industry, at a rate of 75 to 100%.

Dust has been controlled via filters since the 1930s due to the spreading awareness of the silicosis risks. Also in those years, protection measures on machines (e.g. presses) were installed. The pressures to remedy internal pollution mainly came from work councils. Other air emissions have been controlled via fuel and raw material composition (Cadmium was removed from the body). Fluorides and dust are retained by chalk filters and dust collectors.

Depending on the local situation, solid waste from faulty products is recycled in the mass at a rate of 60 to 100%, the rest being dumped on company or public waste sites.

The specific energy consumption was reported with 2000 kcal/m2 (including all energy consumptions, even those not directly related to production like heating of the factory etc.) for the whole process and 440 to 480 kcal/kg for the firing alone.

All companies interviewed have a clearly defined environmental organisation. The production manager is generally responsible for meeting environmental targets (those set by the regulations or by the firm itself). Under his supervision all operational tasks (maintenance and installation) are performed by his own staff. He will be the initiator for new environmental investments. Information generation, the definition of environmental targets and a back-up for the production manager are tasks performed by an environmental agent in the firm. This agent can be a particular post or an additional task assigned to top management. Investment decisions will have to be approved at top management level.

*5.2.4. France*

Environmental concern is still a rather recent issue for French manufacturers, but particularly noise and dust emissions are generally controlled due to a European directive of 1993, which will soon be applied by the French government and is anticipated by the companies. Water treatment has been introduced to most of them (more than 70%) since the application of the national decree 1 of March 1993, regulating industry emissions.

For fluorine gas emissions and heavy metals in waste water (Pb and Zn) the environmental performances seem to be well below Italian and German regulation standards. Villeroy&Boch is currently the only French manufacturer to dispose of a fluorine absorption device in one of its two factories and none of the other firms is planning to introduce such facilities in the near future.

Noise standards were reported to be at about 50 dBa at one site(at 10 m distance from the plant, when situated in a residential area). Recycling of unfired faulty tiles is at 100% while fired faulty tiles go to company waste disposal sites, agriculture (for use in manure) or the construction industry. 80% of the waste water is recycled and 20% treated in "decantation" basins or even with flocculation units. Residues from waste water treatment are either recycled in the raw clay mass or in the construction industry.

The installed dust collectors and silencers are bought from specialised producers, who offer devices for a wide range of pollutants and flow capacities. As in Germany, they generally did not develop their devices for fine ceramics production, except for Italian depollution device manufacturers, which seem to have a fair market share in France.

The specific energy consumption is reported to be about 1600 kcal/kg (mass preparation, pressing, drying, firing, quality control) for single-fired wall tiles (faulty tiles are not counted in weight but in energy consumption). The best value for glazed floor tiles is 2140 kcal/kg (as for wall tiles, whole process including energy for faulty tiles - 10%).[49]

There is no separate department dealing specifically with environmental issues, but in general the production manager is responsible for all environment related tasks, including planning and information generation. Nevertheless, France Alfa has one employee for the entire group, specifically in charge of maintaining contacts with the DRIREs (local public authorities in charge of environmental issues). Villeroy&Boch relies on the same organisational structure as in Germany.

### *5.3. Employment and labour dimension*

#### *5.3.1. Italy*

As shown in table 6, the estimated total number is about 500 employees.

The impact on employment has been of minor importance in the direct employment of ceramic tile firms of the Sassuolo district (100 employees out of a total employment of 21,000 in this sector), mainly in routine maintenance of abatement devices (e.g., changing filter “sleeves”). The installation of the abatement devices is generally done by the producers of these devices.

Almost 70% of total employment induced by environmental regulations is in the firms producing pollution abatement devices (270 employees)[50] and in those supplying technical advice services, transport of residuals, chemical and physical analyses (75 employees)[51]; whereas, 12% is in the public sector (60 employees)[52], in particular in environmental controls specific to ceramic tile production.

#### *5.3.2. Spain*

Even though technicians in many firms have attended specific courses on the environmental problems related to ceramic tile production, there are no full time environmental jobs within the firms.

From the point of view of their effect on employment, the impact of projects for improving the environment seems to be negligible. No ceramics firm envisages job creation as a part of environmental management. Waste collection and treatment systems are installed in all cases with a view to automatisation avoiding the need to use the ceramics firm's own human resources and reducing to a minimum maintenance requirements provided by the installing firm.

### *5.4. Costs of the pollution abatement technologies*

Because of the very restrictive legislation, Italian firms are those with the highest pollution abatement costs.

Table 7 shows an estimate of the average composition of the abatement costs in the ceramic tile district of Sassuolo: if compared with the average production cost, abatement cost amounts to 5-8% of total production cost. The main component of abatement cost is the air treatment, while 40%

[49] Société Française de Céramique.

[50] From our interviews with 5 firms producing abatment technologies we have calculated the total amount of their employment equal to 230. To estimate the total employment in the the firms producing abatement technologies we have adopted the following method. First of all we assume that the number of employees is proportional to the firm’s turnover; we know, from a survey prepared by the association of producers of production technologies (Acimac) that in 1994 total turnover in this sector was 2,995 milliard lire, 31,8% achieved in Italy, about 925 milliard lire. We know that abatment technologies are largely sold in Italy and, since investment in abatment technologies roughly amounts to 10 per cent of total investment, we can then estimate that more or less 100 milliard lire would be the total turnover of the producers of abatment technologies. Given that the total employment in the firms producing machines is 7,593 with a turnover of 2,993, this gives us an estimate of 270 employees in the firms producing abatment technologies. Cf. table 7.

[51] These data have been estimated by Michele Carnevali by interviewing many private service firms and by conducting a direct survey in the public health services in the provinces of Modena and Reggio Emilia. Cf. Carnevali (1995).

[52] Cf. Carnevali (1995).

of the total is the cost of electrical energy used for abatement devices. In terms of investment costs, pollution abatement techniques are almost 10 per cent of total investment in a new plant.

Pollution abatement costs can be expected at a slightly lower level in Germany, while they will be clearly less in France and Spain.

*5.5. An overview*

The main results emerging from the analysis conducted in this section are the following:

1. environmental problems generated by ceramic tile production are noticeably affected by the physical characteristics of the area where production activities are located,
2. there is a wide divergence in environmental regulations and enforcement in the countries examined,
3. employment induced by environmental regulations regarding ceramic tile production is negligible,
4. abatement costs represent a low proportion of total production cost,
5. environmental performances are largely affected by institutional settings.

Let us consider these five results in turn.

First of all, environmental problems in ceramic tile production are becoming extremely acute, not so much because of the specific characteristics of the technical process and materials employed, as because of the concentration of ceramic tile production in a limited industrial area adjacent to residential zones. Hence the environmental problems are pressing in the ceramic tile district of Sassuolo in Italy and not in France or Germany, which have ceramic tile firms scattered all over the country. Even though Spain has a production structure characterised by a high concentration of firms in a limited area, environmental problems appear less pronounced than in Italy, because of less pressure from organised groups of inhabitants and from trade unions, and because of very permissive national legislation on the environment, which is only recently catching up with EU directives. To a lesser extent, the different geographical characteristics of the Sassuolo district in Italy (in a very densely inhabited area on the conoids of a river) and the Castellón district in Spain (in a very windy region) might also explain why environmental problems seem less urgent in Spain.

Second, with regard to the different environmental legislation it should be mentioned that in Emilia Romagna, which has the most restrictive legislation, environmental problems (mainly due to particle emissions and dust) at first emerged as internal to the establishment and were identified by trade unions and the local health authority. Cleaning the workplace from dust generated external problems for the inhabitants of houses in the surrounding area. Severe limits on emissions (initially gaseous emissions and later water emissions) were set by the local authority well below the national threshold (i.e. much more stringent). In contrast with this experience, which goes back decades, Spain has a very recent legislation, while Germany and France have a long tradition on environmental emission standards. However, whereas Germany has environmental standards similar to those applied in Italy at national level, though less restrictive than in the Sassuolo district, the absence of concentration makes those limits adequate. In the case of France there are not specific limits for ceramic tile production and French regulations define threshold emissions for flow masses much higher than those actually emitted by the ceramic tile production process, and in this way the regulations appear to be permissive.

Third, given this institutional context, it is not surprising that only in Italy have the environmental regulations induced an increase in employment, even though it is not significant: it slightly exceeds 500 units that include 4% of total employment in the sector producing machines for the ceramic tile firms and 0,5% of the employment in the ceramic tile sector in the Sassuolo district, the other employees being in the public sector. In Spain, the various projects carried out to keep abreast of the new regulations have had no effect on the number of employees.

Fourth, again because of the institutional settings, Italy is the only country in which firms bear a significant cost for pollution abatement. However, since the new capital goods incorporate the best environmentally friendly solutions, the adoption of the new techniques not only reduces the total production cost per unit of output, but also the overall share of abatement costs.

Lastly, in the country to country comparison of the environmental performances of ceramic tile firms, it emerges that the different institutional settings largely account for the different behaviour of the firms on environmental issues: a different behaviour that is expressed by different strategies, and structures, and that is based upon firm-specific core capabilities. However, such differences may not simply be stigmatised as a nation specific behaviour. We have found that some Spanish firms consider environmental issues a potential factor of instability in the competition with Italian producers. In fact, some Spanish firms are now adopting end-of-pipe technologies and try to take advantage by proposing themselves as the most environmentally friendly producers, with the related negative effect on the image of all other producers. The response of Spanish firms is not uniform, neither is it likely to become so: larger firms, oriented towards export, are trying to catch up with the environmental standards of the Italian firms in the Sassuolo district, while smaller firms continue to work in the traditional conditions.

Even in the Sassuolo district, the response of the firms to changing environmental settings is not a uniform one. Some firms would gain a greater advantage from their leadership in technology and in the adoption of abatement technologies and energy saving techniques. Other firms will maintain the average trend of environmental standards as they are defined by the current regulations. And in this context, the actions of the biggest machine producers are revealing: they too will play the environmental card as a way of increasing their market share, and it is noteworthy to note that only a few of these machine producers have really environmentally friendly processes of production.

## 6. CONCLUSION

### *6.1. The impact of environmental regulations on employment, pollution abatement costs and competitiveness*

The environmental issue has an overall limited effect on employment in the ceramic tile industry in the four countries. In Italy almost 70% of the employment induced by environmental policy (about 350 jobs) has concerned producers of abatement technologies. Such technologies were originally produced by German, French and Italian firms manufacturing abatement devices for various sectors whose production had gaseous emissions. These were, in fact, the first kind of emissions that were submitted to checks. The abatement devices for gaseous emissions were built with aspirators, fans and pipes. At the end of the 1970s there was a strong increase in the demand for these abatement devices. This demand was mainly concentrated in the Sassuolo ceramic tile district. At that time firms producing abatement technologies were located outside the district. They started to subcontract pipe production to small mechanical engineering firms located within the Sassuolo district. These small firms (with less than ten employees) subcontracted to other local firms which specialised in specific operations like calendering, bending or in assembling operations directly in the yard. Firms producing abatement technologies have displaced the firms which were originally market leaders essentially thanks to two relative advantages. First of all, the continuous contacts with machine producers and ceramic tile producers (face to face contacts, frequent visits to the workshops) created easier access to technical information, specific to tile production and increased the rapidity in tuning and modifying plants. Moreover, the proximity to the market reduced transport costs. Second, local producers of abatement technologies benefited from greater organisational flexibility based upon a network of local specialist subcontractors: thanks to long-standing co-operation, subcontractor firms are not compelled to provide too much detailed technical specifications, nor have they to formalise buying contracts.

Abatement devices for ceramic tile production, as well as production technologies, are produced almost totally in Italy. Also the producers of production technologies have had to take into account environmental problems: very often, the solution to an environmental problem does not require a new machine (e.g., a treatment machine), but it needs to plan a plant with different characteristics with regard, for example, to shed sizes and machine lay-out; or it needs a different design for a single piece of production machinery.

Currently, environmental issues do not affect competitiveness in the ceramic tile sector: neither in Emilia Romagna, nor in a country with stringently applied regulations like Germany, nor in a country like France with less severe environmental standards, nor where there are very permissive attitudes, as in Spain. Competition in the ceramic tile sector is largely influenced by other variables that influence tile price, like energy and labour costs, scale and synergy effects due to geographical concentration and technological factors such as design and glazes.

The main results emerging with regard to the four countries are the following.

First of all, Italian producers of ceramic tiles, leaders in the world market, are facing a growing price competition coming from Spain and Portugal. The competitive advantage of the producers in the Sassuolo district is still important, even though the growth of exports of machines for ceramics has given impetus to a more rapid diffusion of new technologies. One important strategy of the biggest firms in the district is to increase their output abroad both to expand their capacity closer to the end market and to overcome increasing limits to expansion within the district (see pgr. 6.2.1).

Second, the export trend for Spanish tile producers and their output is increasing significantly. Even though the majority of Spanish producers perceive environmental problems as present but not as urgent, the largest firms are currently adopting abatement technologies with an eye on forthcoming changes in environmental legislation, and in order to cope with the Italian competition which is trying to take advantage of their comparatively better environmental performances. On the development of solutions to specific environmental problems, research institutions like the Asociacion de Investigación de las Industrias Ceramicas (AICE), partly publicly funded, and the Ceramic Technology Institute of Valencia, play an important role.

Third, with regard to Germany, ceramic tile firms are suffering greatly from mainly Italian imports. Being dependent on Italian design and technology, they are unable to increase their productivity in the short term (limitations due to antiquated production sites) and to compensate significantly higher energy and labour costs. Their strategy therefore is to shift production to product categories where competition is less intense, namely the special non-residential and large format segment or even to de-locate production (as for Villeroy&Boch).

Fourth, although having an even smaller market share in their own country (30%), French manufacturers are very competitive compared to German firms. Their productivity rate being similar to Italian standards, wages and energy costs being very low compared to Germany (energy and work force are 30 to 40% more expensive in Germany), French manufacturers do not complain much. In addition, they use up-to-date equipment due to large investments in the 1990s. The picture is certainly influenced to a great extent by the France Alfa group, with its important production and good links with Italy through its owner Fin Riwal. However, Sarreguemines is also very confident about the future and like France Alfa plans to expand its production capacity.

Fifth, compared with France, environmental performances are very good in Germany, especially for air pollutants. German firms have more abatement devices, for a wider range of pollutants and of an explicitly defined environmental structure in their organisation. One might hence suppose that their environmental costs are significantly higher than in France. If we consider energy as a separate issue, environmental considerations have only a secondary role vis-à-vis competition, but an energy tax (seen as an environmental measure) could have considerable influence on competitiveness in the tiles sector, given that energy accounts for about 15% in the cost structure. The secondary role of the environment for competition is also true for France, where environmental standards and performances are inferior to Germany. All manufacturers stated clearly that the environment is not a competitiveness issue for them. In addition, due to the very recent 1993 decree (regulating emissions for industry plants) none of them expects the standards to be tightened in the foreseeable future.

### *6.2. Employment and sustainability in two alternative scenarios*

So far we have considered the conclusions that emerge from an analysis of the current conditions. Let us now consider a prospective analysis of the impact on sustainability and on employment of two alternative scenarios.

#### *6.2.1. Present trend in output in the four countries, given the different standards currently in force*

Within the first scenario we consider the impact on sustainability of present trends in output with technological changes along the known technological trajectories currently explored.

We foresee: no environmental problems in France and Germany, severe problems in Spain (due to water depletion) and in Italy (due to concentration of emissions and transport).

In the case of Spain, the adoption of recycling and purifying techniques would become necessary in order to cope with use of water for agriculture and industrial uses. In fact, as emerges from technical studies, and even from the experience of Italian firms, recycling makes it possible, for several types of production, to reduce almost completely the use of new fresh water.

Critical problems would also emerge in the Sassuolo district where the present trend in output would impose radical changes.

In general, ceramic tile production within the district poses several problems for the analysis of environmental issues. In fact, a crucial ingredient in the success of the firms operating within the district has been the interaction between producers of different stages in the vertically integrated sector (*filière*), from ceramic tile producers to machine producers, colour producers, transport firms and so on. But the high concentration of ceramic tile production thus attained has generated environmental problems not easily solvable with current technologies. The best available technologies for pollution abatement are already in use in ceramic tile firms in the Sassuolo district. Hence, increasing output means increasing the pollution load in the district. Moreover, besides the pollution from factories, CO2 emissions due to transport would be much more significant. As table 8 shows, if no policy measures were adopted to reduce emissions and to reorganise transport within the area, in five time years the present trend in output would generate a significant increase in NOx, CO, HC and CO2 emissions: the whole district, that is part of the area declared as "at high environmental risk", would be in a very critical environmental situation. If a clean technology were discovered, any increase in output within the district would still imply a significant increase in environmental problems related to transport.

In these conditions, a policy based on the delocation of production activity might be pursued in order to reduce the pressure on a very fragile territory, but so far it seems that measures to induce delocation have not been efficient. Firms did not react positively because of their inability to cope with production conditions different from those they have in the district. And this applies not only to ceramic tile firms, but also to firms in every other stage of the vertically integrated sector.

If a ceramic tile firm completely abandoned the district, it would not benefit from the advantages of the interactions mentioned above that are important for the expansion of the firm. Only multi-plant firms could adopt a policy of maintaining some production units within the district while expanding outside the district as a strategy for expanding output. This seems to be a possible interpretation of the recent decision taken by Marazzi to buy FinRiwal: a group that has a significant share of France Alpha, with several plants in France close to the German border, in a country, let it be remembered, with the least restrictive environmental regulations with regard to ceramic tile production.

A long term policy based upon delocation incentives would not, in any case, sidestep the need for a complementary territorial planning policy that should consider the district as the planning unit.

*6.2.2. Reduction of threshold limits*

Let us consider the effects of reducing threshold limits. This scenario considers the effect on a firm's behaviour as mainly induced by command and control approaches. It consists of two parts: (i) considers the extension of standards currently in force in Germany and Italy to other EU countries, and (ii) addresses the case of tightening threshold limits in the Emilia Romagna region.

(i) In this scenario, threshold limits in Germany and Italy would remain unchanged, while they would be tightened in France and Spain. Whereas the Spanish environmental legislation is currently moving towards the adoption of stricter standards (environmental policy in Spain already adopts fiscal incentives to induce firms to reduce pollution, in particular in the case of water emissions), tighter standards are unlikely in France. A decree on air and water emissions has only recently been adopted in this country.

But even if we assume that thresholds are tightened all over the EU, the total effect on employment would be almost proportional to the increased demand for pollution abatement devices. If we assume that threshold limits are tightened all over the EU, it can be conjectured that the number of employees in the production of pollution abatement technologies for ceramic tile production would roughly double, given that total production in other EU countries is almost the same as in Italy. The employment increase will then be mainly in Italy.

(ii) Last, let us consider the case of further tightened environmental regulations in Emilia Romagna. Due to the fact that best available technologies for pollution abatement are already in use in the region, the most probable outcome for the moment would be a limitation of total ceramic tile output.

In such a situation, a growth in demand for ceramic tiles would have to be met from other sources. As Spain has serious problems with the use of water and Germany is not competitive, there might be an international reallocation of production in favour of French and other European producers.

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ANNEX

## List of firms, experts and public officers interviewed

FRANCE
Société Française de Céramique, Service Céramique d'Equipement du Bâtiment, Mr. JP Karpeltzeff
Société Française de Céramique, Mr. Le Doussa
Desvres, Marketing, Mr. Ringue
Groupe France Alfa, Investissement, Mr. Maurel
Groupe France Alfa, Marketing, Mr. Bruno Cassavia
Groupe Sarreguemines, Chef d'Usine, Mr. Pedinotti
Groupe Sarreguemines, Directeur Commercial, Mr. M. France
Chambre Syndicale du Carreau Céramique de France, Mrs. Labarre

GERMANY
Villeroy & Boch, Marketing, Mr. T.E. Wenzel
Villeroy & Boch, Environmental Protection, Mr. DR-ING. R. Probst
Villeroy & Boch, Marketing, Mr. Boch
Heinrich Lühr Staubtechnik, Producer of green technologies, Mr. Castaigner
Hellmich GmbH, Producer of green technologies, Mr. Lohmann
Keller Lufttechnik GmbH+Co.KG, Producer of green technologies, Mr. Vöhringer
Industrieverband Keramische Fliesen+Platten, Mr. Oehm
Agrob Wessel Servais, ABK Gruppe, Marketing, Mr. U. Klein
Agrob Wessel Servais, ABK Gruppe, Responsible for Environmental Matters, Mr. Schumann
Boizenburg Gail Inax, Technical Director, Mr. K.-H. Fabel

ITALY
Igiene Pubblica USL Sassuolo (MO), P.I. Graziano Busani
FinRiwal, Fiorano Modenese, Dott. Gabriele Canotti
Eco Geo, Sassuolo (MO), Ing. Franco Carnevali
Eco Geo, Sassuolo (MO), Sig. Michele Carnevali
Acimac (Associazione costruttori di impianti e macchine per la ceramica) Modena, Direttore, Dott. Paolo Gambuli
Assessorato Ambiente e Territorio, Provincia di Modena, Caposervizio, Dott. Giovanni Rompianesi
Ipeg, Sassuolo, Ing. Mauro Poppi
Assopiastrelle, Sassuolo (MO), responsabile statistiche, Dott.ssa Marisa Cavatorti
Assopiastrelle, Sassuolo (MO), caposervizio relazioni economiche e commerciali, Dott. Luciano Galassini
Assopiastrelle, Sassuolo (MO), environment and safety division, Dott. Andrea Canetti
Assopiastrelle, Sassuolo (MO), capo servizio relazioni sindacali, Dott. Simone Gradellini
C.A.M.I. Depurazioni S.r.l., Spezzano (MO), owner, Sig. Minghelli
Cefla S.c.r.l., Imola (BO), Direttore del settore Depurazione e Ingegneria ambientale, Ing. Giuseppe Calzolari
Eurofilter S.r.l., Casalgrande (RE), Responsabile tecnico commerciale, Ing. Paolo Cerretti
Eurofilter S.r.l., Casalgrande (RE), Direttore generale, Ing. Montecchi
Centro Analisi Technair S.r.l., Modena, Responsabile settore fisico, Dott.ssa Maria Elisabetta Bortolani
Sacmi Coop mecc. Imola S.c.a.r.l., Imola (BO), Direttore generale, Ing. Giulio Cicognani

S.I.T.I. S.p.a., Società impianti termoelettrici Industriali, Marano Ticino (NO), Direttore generale, Ing. Angelo Barattoni

SAT Servizi ambiente Territorio S.p.a., Sassuolo (MO), responsabile ufficio acquedotto, Sig. Andrea Scurani

SAT Servizi ambiente Territorio S.p.a., Sassuolo (MO), responsabile servizi di rete, Sig.ra Patrizia Zagni

Camera di Commercio, Modena, Responsabile Ufficio Studi, Dott. Raffaele Giardino.

SPAIN

Ascer, Asociación Española de Fabricantes de Azulejos, Pavimentos y Baldosas Cerámicas

Itc-Aice, Instituto de Tecnologia Cerámicas - Asociación de Investigación de las Industrias Cerámicas

Regional Environmental Protection Agency (Conselleria de Medio Ambiente del Gobierno Regional de Valencia):

- Servicio de Calidad del Ambiente Atmostérico
- Servicio de Recursos Hidricos
- Servicio de Residuos Sólidos

Ceramic tile firms:

- Alfa Cerámica (Nules)
- Arcilla Industrial (Vila Real)
- Atomizadora, SA (Onda)
- Azulejos Plaza (Alcora)
- Azulindus & Marti (Monda)
- AZU-VI, SA (Vila Real)
- Cerámica Bopi (Onda)
- Estudio Cerámico (S. Joan de Moró)
- Garogrés (S. Joan de Moró)
- Gres de Nules (Nules)
- Hijos de F. Gaya Fores (Onda)
- Keraben (Nules)
- La Pinosa (Alcora)
- Manuel Soler Gómez (Castellón)
- Mazari (Alcora)
- Taulell (Castellón)
- Tilesa (Alcora)

Producers of frits, enamels and colors:

- Cerdec Ibérica (Nules)
- Coloresmalt (Castellón)
- Esmaltes, SA (Alcora)
- Ferroenamel Castellón)
- ITACA (Pobla Tornesa)

Producers of pollution abatement technologies:

- Unisystems (Vila Real)

List of figures and tables

Table 1   Ceramic tile markets in European countries and in the United States (1994)

| Country | Market size | Market shares of: | | | |
|---|---|---|---|---|---|
| | | national producers | Italian producers | Spanish producers | other producers |
| | million m2 | % | % | % | % |
| Italy | 188,8 | 95,0 | 95,0 | 2,4 | 2,6 |
| Germany | 187 | 25,1 | 50,0 | 6,9 | 18,0 |
| Spain | 180 | 99,1 | 0,5 | 99,1 | 0,4 |
| United States | 117,7 | 45,9 | 20,7 | 10,4 | 23,0 |
| France | 93,8 | 28,6 | 45,2 | 9,0 | 17,2 |
| United Kingdom | 36,9 | 28,7 | 15,1 | 22,7 | 33,5 |
| Greece | 30 | 12,0 | 50,2 | 21,1 | 16,7 |
| Belgium and Lux. | 30 | 8,7 | 38,8 | 9,9 | 42,6 |
| Holland | 23 | 27,0 | 36,7 | 12,6 | 23,7 |
| Austria | 16,1 | 2,5 | 79,7 | 5,0 | 12,8 |
| Switzerland | 13,8 | 7,2 | 52,7 | 5,1 | 35,0 |
| sum | 917,1 | | | | |

Source: Assopiastrelle-Prometeia (1995)

Table 2 Number of firms, employment, output, exports and imports in the ceramic tile industry in the four countries

| | 1980 | 1985 | 1990 | 1991 | 1992 | 1993 | 1994 |
|---|---|---|---|---|---|---|---|
| Italy | | | | | | | |
| Firms | 470 | 362 | 347 | 351 | 347 | 343 | 345 |
| Employees | 45.800 | 31.900 | 31.500 | 30.900 | 30.300 | 29.800 | 30.800 |
| Output (million sq.m.) | 336 | 311 | 447 | 432 | 435 | 459 | 510 |
| Exports (million sq.m.) | 149 | 158 | 217 | 217 | 233 | 277 | 325 |
| Imports (million sq.m.) | | | | | | | 9,5 |
| Sassuolo district* | | | | | | | |
| Firms | 259 | 211 | 202 | 194 | 195 | 197 | 190 |
| Employees | 30.500 | | 21.400 | 21.000 | 20.300 | 20.400 | 21.000 |
| Output (million sq.m.) | 234,9 | | | | | 364,2 | 404,2 |
| % of national output | | 72,6 | 73,1 | 74,4 | 74,9 | 79,4 | 79,2 |
| Exports (million sq.m.) | 101,4 | | | | | | |
| Spain | | | | | | | |
| Firms | 195 | 203 | 212 | 211 | 200 | 197 | 185 |
| Employees | 15.100 | 12.500 | 13.100 | | | | |
| Output (million sq.m.) | 116,0 | 149,9 | 219,0 | 228,0 | 261,0 | 281,0 | 320,0 |
| Exports (million sq.m.) | 33,1 | 55,3 | 92,9 | 95,1 | 101,5 | 126,5 | 158,4 |
| Imports (million sq.m.) | | | | 2,5 | 3,1 | 1,5 | 1,6 |
| Castellon district** | | | | | | | |
| Firms | 162 | 145 | 156 | | | | 134 |
| Employees | 12.800 | 11.700 | 12.300 | | | | |
| Germany | | | | | | | |
| Firms | | | | | | | 20 |
| Employees | | | | | | | 8.800 |
| Output (million sq.m.) | 80 | | 72 | | 75 | | 69 |
| Exports (million sq.m.) | 29 | | 26 | | 25 | | |
| Imports (million sq.m.) | 54 | | 77 | | 105 | | |
| France | | | | | | | |
| Firms | | | | | | | 21 |
| Employees | | | | | | | 3.700 |
| Output (million sq.m.) | | | 36,9 | 40,0 | 43,2 | 43,8 | 46,0 |
| Exports (million sq.m.) | | | 10,0 | 12,6 | 14,5 | 15,9 | 18,7 |
| Imports (million sq.m.) | | | 65,1 | 64,3 | 62,2 | | |

* Data refer to the provinces of Modena and Reggio Emilia
** Data refer to the province of Castellon

Sources:

Italy: Assopiastrelle (1994)
Spain: 1980, 1985,1990: Camara Oficial de Comercio, Industria y Navigacion de Castellon;
Germany: Industrieverband Keramische Fliesen+Platten
France: Chambre Syndacale du Carreau de Céramique de France

Table 3 Firms, turnover, employment and degree of vertical integration in the plant production sector in Italy

| firm | employment direct[a] | employment total[b] | turnover (mld. It. Lit) total | turnover (mld. It. Lit) *per capita*[c] | what the firm produces internally or within the group | firm's subcontractors number | firm's subcontractors type |
|---|---|---|---|---|---|---|---|
| Sacmi[d] | 700 | 1100 | 650 | 0,591 | plant building and utility services design and layou produces: atomizers, presses, kilns, cogenerators | various | dependent |
| Siti[d] | 370 | 555 | 316 | 0,569 | presses, dryers, kilns | various | independent |
| Nassetti[d] | 250 | 500 | 254 | 0,508 | glazing machines, serigraphic machines, selecting lines | various | owned or controlled |
| Welko[d] | 270 | 270 | 110 | 0,407 | everything, except standardized components | only a few | independent |
| Total | 1590 | 2425 | 1330 | 0,548 | | | |
| Tile machine production sector[e] | | 7953 | 2995 | 0,377 | | | |

[a] Number of employees directly employed within the firms of the group
[b] Number of employees directly employed by the firms of the group plus those employed by the subcontractors
[c] Total turnover divided by total employment (direct plus indirect)
[d] Source: our interviews with firms
[e] Source: Acimac (1995)

Table 4 Firms, turnover and employment in the production of emission abatement technologies in the ceramic tile district of Sassuolo (Italy)

| firms | turnover (mld Lit.) 1994 | no. of employees 1995 | employees in subcontracting firms | total employment |
|---|---|---|---|---|
| Producers of cleaning technologies | | | | |
| Eurofilter | 20 | 60 | 20 | |
| Cami | 4 | 13 | 7 | |
| Medici | 3 | 20 | a few | |
| Progeco | 3 | 25 | 8 | |
| Manicardi ecologia | n.a. | 20 | n.a. | |
| Filtertek | n.a. | 10 | n.a. | |
| Cefla | n.a. | n.a. | n.a. | |
| 3 small firms | n.a. | n.a. | n.a. | |
| *(a) sum of available data* | *30* | *148* | *35* | *183* |
| Services | | | | |
| Agrindustria | | n.a. | | |
| Centro analisi Technair | | 8 | | |
| Cisdi | | n.a. | | |
| EcoGeo | | 7 | | |
| Studio Alpha | | 10 | | |
| Studio del dr. Vecchi | | 4 | | |
| Effe studio | | n.a. | | |
| Studio Bucciarelli | | 3 | | |
| Laboratorio di analisi chimiche | | 10 | | |
| Laboratorio Stampa e Ranuzzi | | 5 | | |
| *(b) sum of available data* | | *47* | | *47* |
| *(a) + (b)* | | *195* | *35* | *230* |
| *estimated data** | *100* | | | *345* |

***** The hypotheses to estimate turnover and employment in the production of cleaning technologies are the following:
- investment and maintainance cost of cleaning technologies: 10% of total investment
- in 1994, the total turnover of the machine producers was 2995 milliard Lit., 31.8% in Italy
- cleaning technologies are sold mainly in Italy
- the number of employees in the production of cleaning technologies is proportional to firms' turnover; to the resulting amount (270 employees) has been added the number of employees in service firms (75), as estimated by Carnevali (1995)

Sources: our interviews with firms, Acimac (1995), Carnevali (1995)

Table 5 Limits for gaseous emissions and water emissions as *per* criteria proposed by the Italian commette for awarding the EU ecolabel to ceramic tiles and as defined by the environmental norms in the four countries[a]

| | EU ecolabel proposal | Emilia Romagna[b] | Italy | Spain | Germany | France |
|---|---|---|---|---|---|---|
| Air pollutant (mg/Nm3)[c]<br>T=25°C P=101,3 kPa | (1) | (2) | (3) | (4)[c] | (5) | (6) |
| Particulate matter | 7-50<br>grinding and shaping: 50<br>spray drying 50<br>glazing: 10<br>firing tiles: 7<br>kilns (frits): n.s. | 5-30<br>grinding and shaping: 30<br>spray drying 30-75[d]<br>glazing: 10<br>firing tiles: 5<br>kilns (frits): 30 | 50 (F>0,5 kg/h)<br>150 (0,1>F<0,5kg/h) | 500 for plants built before 1975<br>250 for plants built after 1975<br>150 for plants built after 1980 | 50 | 50 (F>1kg/h)<br>100 (F<1kg/h) |
| Pb | | 0,5<br>5 frits kilns | 5 (F>25 g/h) | | 5 (F>25 g/h) | 5 (F>25 g/h) |
| F | 5 | 5 | 10 (F>50 g/h)[e] | 40 only frits kilns | 5 | 5 (F>500g/h) |
| Nox | | | 1500 (F>5 kg/h) | | 500[f]<br>1800[g]<br>1500[h] | 500 (F>25kg/h) |
| Sox | | | 1500 (F> 5kg/h) | 850 | 500[i]<br>1500[l]<br>1000[m] | 300 (F>25kg/h) |
| Water pollutant (mg/l)[n] | (1) | | (7) | (8) | (9) | (10) |
| Total suspended materials | 80-200 | | 80-200[o] | 300 | 80 | 100 (F>15 kg/day)<br>35 (F>15 kg/h) |
| COD | 160-500 | | 160-500[p] | 500 | 80 | 300 (F<50 kg/day)<br>125 (F>50 kg/day) |
| BOD | 40-250 | | 40-250[p] | 300 | 80 | 100 (F<15 kg/day)<br>30 (F>15 kg/day) |
| Zn | 0,5-1 | | 0,5-1 | 20 | 2 | 2 (F>20 g/day) |
| Pb | 0,2-0,3 | | 0,2-0,3 | 0,5 | 0,5 | 0,5 (F>5 g/day) |
| Cd | 0,02-0,02 | | 0,02-0,02 | 0,5 | 0,07 | |
| Cr6+ | 0,2-0,2 | | 0,2-0,2 | 0,5 | 0,1 | 0,51 (F>5 g/day) |

[a] The pollutants listed in the table are those which are most important for ceramic tile production. Flow mass, F, as specified in brackets to the right of the limit.
[b] When not specified, national limits apply
[c] In Spain limits on air emissions are expressed in terms of different physical conditions. The Decree 833/1975 defines the conditions at T= 0° C (instead of 25° C) and P=1. This means that, being defined at a lower temperature, the the Spanish Nm3 contains more mass (air and pollutants) than the Nm3 used in the table for the other countries
[d] To plants built before 1988 a limit of 75 mg/Nm3 applies
[e] National law sets a lower limit for a generality of plants and the specific limit of 10 mg/Nmc for ceramic tile plants
[f] In general
[g] Roll kiln to fire biscuit
[h] Other kilns to fire biscuit
[i] Sulphur content in clay less than 0.12%
[l] Sulphur content in clay greater than 0.12%
[m] Other kilns to fire biscuit
[n] Ranges refer to concentration values in surface waters (value on the left) and in sewers (value on the right)
[o] 40% less than plant water input flow
[p] 70% less than plant water input flow

Sources:

(1) Ministero dell'Ambiente, *Study for the attribution of an European ecolabel for ceramic floor and wall tiles* , "Criteria proposed for awarding the ecolabel trademark", pp. 11-13, rev. 2, March 1994

(2) Regional law 36/1989
(3) Data from Annex 1 to Ministerial decree 12/7/1990
(4) Royal Decree 833/1975 and following application norms
(5) C. Prieur (19939, Réduction des rejects polluants dans l'environment des usines céeramiques en Europe, L'industrie Céeramique, n. 878
(6) Arreté du 1er Mars 1993, Journal Officiel 28 mars 1993
(7) Laws: 319/1976 and 650/1979
(8) Royal Decree 849/1986
(9) See (5)
(10) See (6)

Table 6 Estimate of employment induced by environmental pressures in the ceramic tile district of Sassuolo (Italy)

| | number of employees |
|---|---|
| Producers of cleaning technologies * | 270 |
| Services (laboratories, technical advice)* | 75 |
| Direct employment in ceramic tile firms * | 100 |
| Public sector (USL, public administration) ** | 60 |
| Total | 505 |

Sources:

* our interviews with firms
** Carnevali (1995)

Table 7 Average pollution abatement costs in the ceramic tile district of Sassuolo (Italy)

| Item of the pollution abatement costs | Lit. per unit of output (Lit/m2 of final | % of total treatment cost | % of total investment cost |
|---|---|---|---|
| Air treatment | | | |
| electrical energy | 110 | 34,4 | |
| materials | 35 | 10,9 | |
| maintainance | 25 | 7,8 | |
| depreciation | 50 | 15,6 | |
| other costs (laboratory checks, ...) | 30 | 9,4 | |
| Total | 250 | 78,1 | 4,5 |
| Water treatment and recycling | | | |
| electrical energy for treating and recyclying | 20 | 6,3 | |
| transport | 5 | 1,6 | |
| depreciation in treating and recycling | 15 | 4,7 | |
| operating costs | 5 | 1,6 | |
| other costs (laboratory checks, ...) | 15 | 4,7 | |
| Total | 60 | 18,8 | 3,0 |
| Other costs (residual treatment, | | | 2,5 |
| noise abatement) | 10 | 3,1 | |
| Total pollution abatement costs | 320 | 100,0 | 10,0 |

Sources: our estimation from interviews, Carnevali (1995)

Table 8 Current situation and trends of the main variables related to production and transport* within the ceramic tile district of Sassuolo (Italy)

| | unit of measure | 1994 | estimated data at the year 2000** | percentage change |
|---|---|---|---|---|
| output | million m2 | 300,6 | 364 | 21,1 |
| total number of vehicles: | | | | |
| within the district | million | 2,97 | 3,8 | 27,9 |
| passing the perimeter of the district | million | 0,95 | 1,1 | 16,0 |
| distance travelled by vehicle | km | 267.026 | 400.819 | 50,1 |
| time travelled by vehicle | hours | 5.694 | 9.587 | 68,4 |
| fuel consumption by vehicle | litres | 20.390 | 32.086 | 57,4 |
| emissions by vehicle | | | | |
| NOx emissions | kg | 424 | 629 | 48,3 |
| CO emissions | kg | 5.357 | 8.894 | 66,0 |
| HC emissions | kg | 464 | 764 | 64,7 |
| CO2 emissions | kg | 11.936 | 18.783 | 57,4 |

* The transport considered are only those related directly and indirectly to the production of ceramic tiles withir the district, they amount to 90% of total transport within the district

* * Estimated data refer to a scenario that takes as given present trends in output and organization of productior and no public measures to reorganize sevices within the area

Source: our elaboration on data from the Demetra Project (Demonstration of the energy methods effectiveness transportation), 1994