RAW MATERIAL FLOWS IN THE EUROPEAN CERAMIC TILE INDUSTRY: CASE STUDY OF ITALY AND SPAIN

Michele Dondi[1], Mónica Vicent-Cabedo[2], Elisa Rambaldi[3], Chiara Zanelli[1], Javier García-Ten[2]

[1]CNR-ISTEC, via Granarolo 64, 48018 Faenza, Italy.

[2]Instituto de Tecnología Cerámica (ITC). Asociación de Investigación de las Industrias Cerámicas (AICE). Universitat Jaume I (UJI). Castellón, Spain.

[3]Centro Ceramico, via Martelli 26, 40138 Bologna, Italy.

1. ABSTRACT

Recent trends in the raw materials market reveal a growing dependence of the European ceramic tile industry on imports from sources outside the European Union. This tendency reflects significant changes in the typologies of ceramic products, which in turn result in a modified batch design and different raw materials. Such an evolution implies an increasing stress on the supply chain, whose role is strategic in terms of resource efficiency and competitiveness of the European industry. Despite the importance of a secure and affordable supply, global knowledge of raw materials flows and medium-term availability is still lacking. In order to fill this gap, the supply chain was examined by quantifying the recent progress of industry demand and trade flows

in Italy and Spain. Current trends are identified and related to trade dynamics and apparent consumption of raw materials, with special care regarding possible criticalities. Raw materials flows are displayed for clays and feldspathic fluxes. Beyond the specific features of each country, the resulting supply patterns are becoming similar everywhere, with an increasing dependence on the same sources.

2. INTRODUCTION

The European ceramic tile industry is a big consumer of a wide array of industrial minerals required to formulate bodies, glazes, engobes and pigments. These raw materials stem not just from domestic sources but are also imported from other European countries or even outside Europe. For these reasons, the supply chain takes on a strategic role, because the efficiency in the access to mineral resources has become a competitive factor among tile manufacturers. On the other hand, the concentration of sources can represent a critical aspect of supply for some raw materials [1].

The ceramic raw materials marketed on a large scale are essentially clays and fluxes, for which there are many different types and alternatives. Clay materials can be broken down into red clays, ball clays, kaolin, etc. [2-3]. Fluxes encompass various kinds of feldspars, including feldspathic sands and nepheline syenite [3-4]. Possible substitutes involve secondary raw materials and end-of-life products [5-6]. In addition, many other commodities are used by the ceramic industry (talc, wollastonite, lithium minerals, borates, and so on).

Despite its relevance for the European ceramic tile industry, no overall picture is available for the raw materials supply chain. Here, a first attempt is made to compare the two major tile manufacturers in Europe (Spain and Italy), which together account for most of the demand on the international ceramic raw materials market. The Italian and Spanish ceramic tile districts represent about 3% and 4%, respectively, of total world tile manufacture (China included) and about 12% and 14%, respectively, of total world tile exports [7]. The goal is to analyse the supply chain of the Castellón and Sassuolo districts: describing current trends in the production of ceramic tiles, evaluating their repercussion on the demand for industrial minerals, quantifying raw materials flows, and highlighting possible criticalities.

3. EXPERIMENTAL APPROACH

One of the main problems faced on preparing this paper was the difficulty in obtaining representative and comparable data on tile production and raw materials consumption of the main ceramic tile typologies manufactured in both countries. For this reason, this section deals with the data sources used. Note that data on raw materials consumption refers exclusively to ceramic tile bodies, so that the materials for frits, engobes, glazes and calcined pigments are excluded. The following ceramic tile typologies, classified according to the groups defined in ISO 13006 and/or EN 14411, were considered:

- Porcelain tiles (BIa).
- White-firing floor tiles (BIb).
- White-firing wall tiles (BIII).
- Red-firing floor tiles (BII)
- Red-firing wall tiles (BIII).

Global ceramic tile production data, in square metres, were obtained from ASCER (Spanish Ceramic Tile Manufacturers' Association) [8]. To break down overall production into the different ceramic tile typologies existing in Spain, data from the Annual Competitive Position Report (IPAC) drawn up by the ITC Market Observatory was used. Data for Italian production were obtained from the national statistical surveys provided yearly by Confindustria Ceramica [9].

Data on ceramic tile production were converted into tonnes of raw materials based on assumptions of average values of tile thickness and bulk density (tile weight, kg/m2), as well as loss on ignition and wastage during manufacturing, for each product typology. To calculate the apparent consumption of the main types of raw materials, several data sources were consulted. For the imported raw materials (ball clays and feldspars) national statistics on raw materials imports and exports were consulted (ESTACOM in Spain [10] and EUROSTAT in Italy [11]), assuming that not all the imported raw materials were used to produced ceramic tile bodies, but also other products like engobes or sanitary ware. Data on Spanish red-firing clays were calculated from Spanish red-firing floor and wall tile production, given that all raw materials used are domestic. Finally, data on the consumption of other local raw materials such as kaolin, quartz and calcite were calculated from tile production data, considering average compositions for the white-firing ceramic tiles, and the information given by local suppliers.

Indicators were used to estimate the degree of market concentration, apparent consumption of raw materials, dependence on imported raw materials and distance from mine to tile-making plant. The amount of competition along the supply chain was estimated through the Herfindahl–Hirschman Index, HHI:

$$HHI = \sum_{i=1}^{N} s_i^2$$

where si is a country's share in the supply chain, and N is the number of countries. Thus, HHI ranges from 1/N to one, with values below 0.15 indicating an unconcentrated supply chain; HHI between 0.15 and 0.25 indicates a moderate concentration, while HHI > 0.25 points to a high concentration.

The dependence on imports was expressed as Import Reliance (IR), which is the percentage of imported raw materials on the apparent consumption.

4. RESULTS AND DISCUSSION

Ceramic tile production

The ceramic tile production in the last decade in the Italian and Spanish districts is shown in figure 1. The output of different tile typologies is expressed in square metres manufactured and raw materials consumption.

In Italy, a progressive and slow conversion to porcelain tiles took place and in 2016 reached 86% of overall production. This figure is even higher on considering raw materials consumption, this being over 90% for porcelain tiles. Other whiteware types not included in the BIa class (floor tiles, wall tiles - monoporosa, birapida - and klinker) are gradually diminishing and represented 3.5% in 2016. A similar trend features all products based on red-firing bodies (including floor tiles, wall tiles - monoporosa, birapida - and rustic cotto), which in 2016 account for 9%.

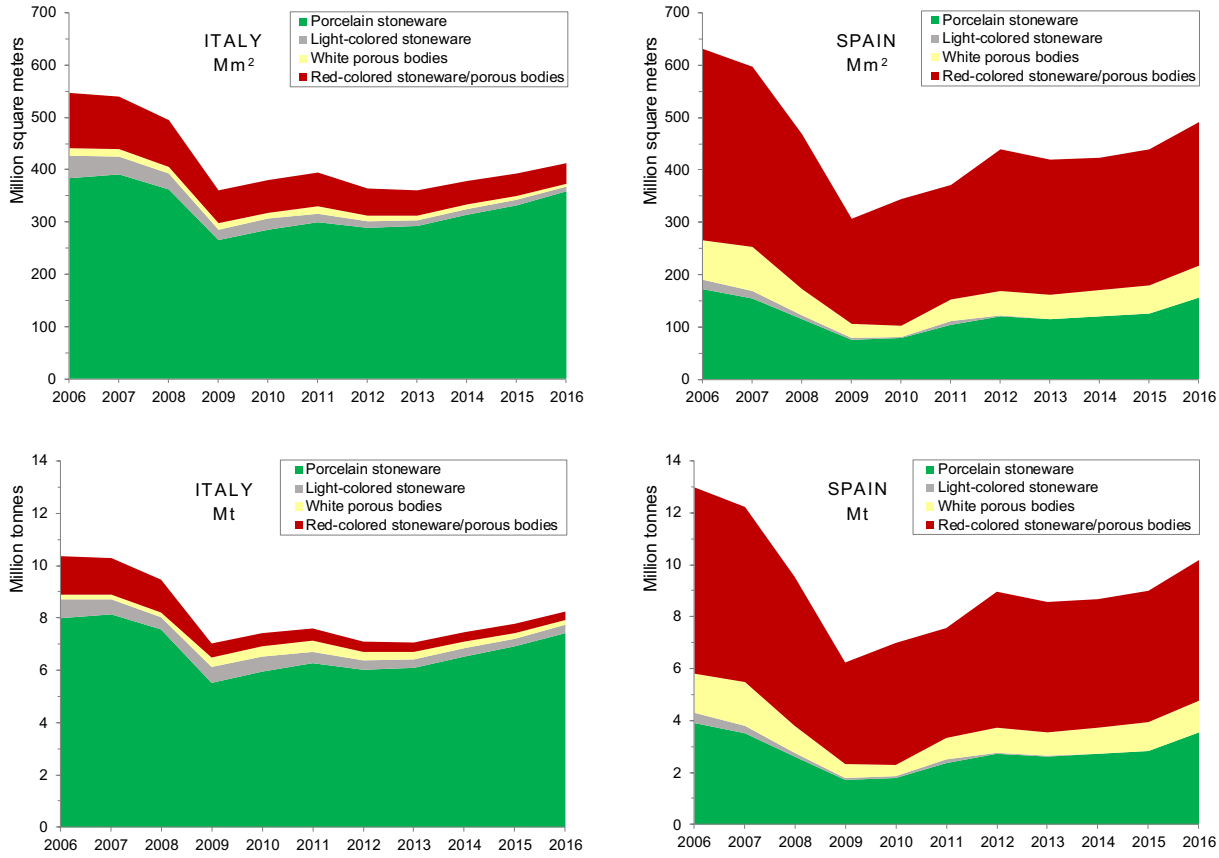

Fig. 1. *Ceramic tile production (in square metres) and raw materials consumption (in million tonnes) for different tile typologies in Italy and Spain in the period 2006-2016.*

In Spain, after the recession of the years 2006-2009, there was a progressive increase in the production of ceramic tiles until 2016, but without reaching the value of 2006. Some typologies, such as white-firing floor tiles, were no longer produced due to their similarity to porcelain tiles, and the production of other red-firing products, mainly extruded (not included in the figure), decreased markedly during this period moving from 7% to 1%. It is interesting to note that during the recession (2006-2009) the ratio white-firing/red-firing declined from 42/58 to 35/65. In contrast, from 2009 on, this

ratio increased to 44/56 in 2016. This trend continued in 2017 and 2018, reversing the value of the ratio, which means a clear trend towards the production of white-firing tiles in Spain.

The consumption of raw materials followed a similar trend to that of production, although somewhat more pronounced in favour of white-firing tiles due to the higher raw materials consumption per square metre white-firing bodies.

Use of raw materials

The comparison of the demand for raw materials (including: ball clays, red-firing clays, kaolin, feldspars, feldspathic sands, and others) from the Italian and Spanish ceramic tile districts in 2006 and 2016 is shown in figure 1, broken down into the various ceramic tile typologies.

Apparent consumption (i.e. domestic production + imports – exports) of clays and feldspars in the last decade is illustrated in figure 2.

In Italy, from 2010 to 2015, demand kept rather steady at around 3 Mt ball clays and 4 Mt feldspathic materials. Since 2015, the apparent consumption grew to 4.8 Mt and 3.8 Mt for feldspars and ball clays, respectively, before a slight decrease in the last few years. The gradual abandonment of red clays continued, even though at a very slow pace, since the shift to white-firing floor tile bodies already occurred across the 1980s and 1990s [12].

In Spain, in the period under analysis, the apparent consumption of red clays remained stable at around 5 Mt until 2016, declining from that year onwards as a result of the decrease in the production of red-firing tiles. Regarding the consumption of ball clays, both domestic and imported, there was a progressive growth in the apparent consumption due to the increase in the production of white-firing tiles. The slowdown in 2018 may be attributed to adjustments in the imported clay stocks located in the spray-drying plants and in the port of Castellón, given that the production of white-firing tiles continued growing at the same rate. Regarding the consumption of feldspar, after a moderate consumption increase until 2014 (0.8-1.1 Mt), there was an important demand for feldspar, reaching 2.6 Mt in 2018, which must be mainly associated with the growth of porcelain tile production.

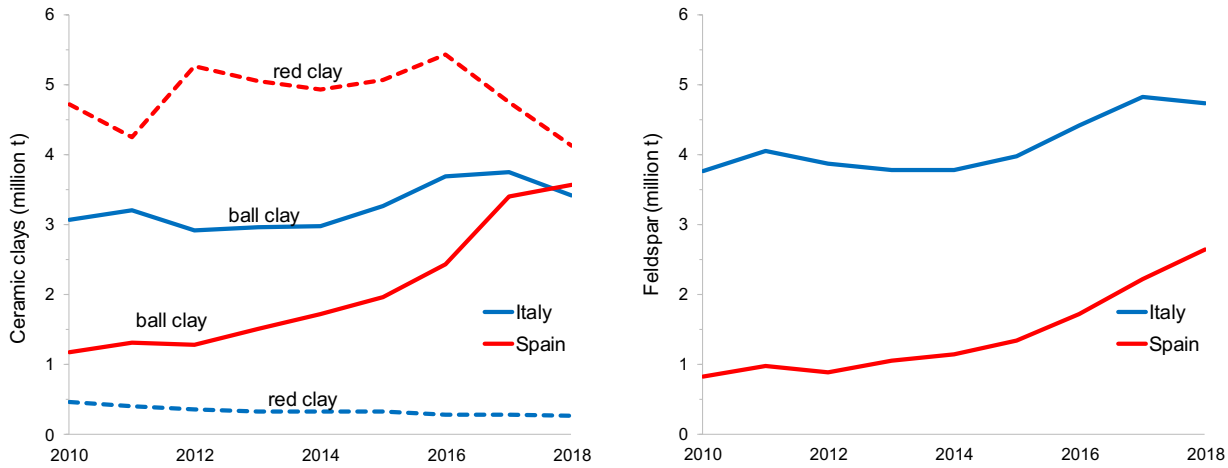

Fig. 2. *Apparent consumption of ceramic clays (left) and feldspars (right) by the ceramic industry in Italy and Spain.*

Raw materials supply chain

The demand for raw materials for ceramic tiles was satisfied in Spain and Italy with a different recourse to domestic and imported raw materials (figure 3).

For Italy, the Import Reliance (IR) decreased slightly in 2010-2014, passing from 60% to 56%, following the efforts to damp the batch cost by using domestic raw materials. Since 2015, the IR value grew to 66%, as a result of the larger production of porcelain tiles, with increasing mean size and thickness, and particularly the manufacture of large slabs. The fraction of imported raw materials increased slightly in a parallel way since 2010 to 2018 for both plastic and non-plastic raw materials, which reached a IR close to 80% and 50%, respectively.

The Spanish IR in the period 2010-2018 is lower than that of Italy, as a result of the higher red-firing tiles manufactured, produced exclusively with domestic clays, and the use of other domestic white-firing raw materials such as clay, kaolin, quartz and calcite to manufacture both white-firing wall tiles and porcelain tiles. In 2010 the IR value was low (25%) and was mainly due to the scarcity of domestic feldspars with the appropriate characteristics for being used in porcelain tiles. Then, the IR declined in 2012 as a result of the greater increase in the manufacture of red-firing with respect to white-firing tiles. However, from 2012 onwards, there was a steady increase in import reliance until 2016, due to the stabilisation in the production of red-firing tiles and the increase in white-firing products in which imported clays and feldspars are commonly used. From 2016 on, the increase in the import reliance is more pronounced, particularly for plastic raw materials, reaching a value close to 45% in 2018. This trend is the result of the increase in the ratio white-firing/red-firing tiles, porcelain tiles being the product with the greatest increase.

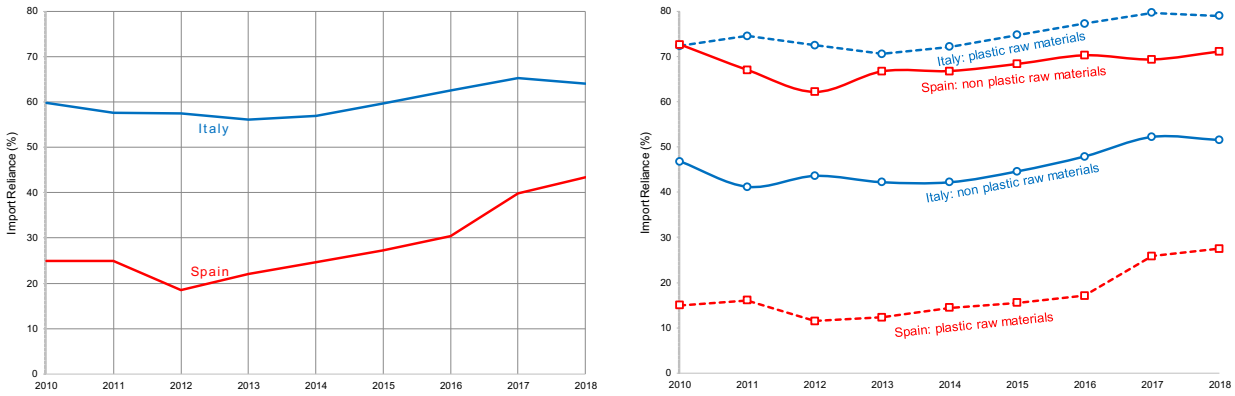

Fig. 3. *Import Reliance for the average batch (left) and separately for plastic and non-plastic raw materials (right) in Italy and Spain in the period 2010-2018.*

The raw materials flow in the last decade is shown in figure 4 in terms of ball clays and feldspars imports.

In the case of Italy, a steady picture may be noted until 2014, clearly followed by a strong rise in imports, particularly from Ukraine and Germany (ball clays) and Turkey (feldspar). The attempt may be noted, since 2015, to diversify the suppliers, with increasing contributions from Romania, Serbia, Portugal, Spain, and Turkey for ball clays, and from France for feldspars.

Spain has progressively increased the raw materials imports as a result of the transition from the manufacture of red-firing to white-firing tiles, feldspar and clay being the main imported raw materials. In the first case due to the scarcity of feldspar operations with the required characteristics and the better quality/price ratio of imported feldspars, while in the second due to the greater plasticity and whiteness of the imported clays.

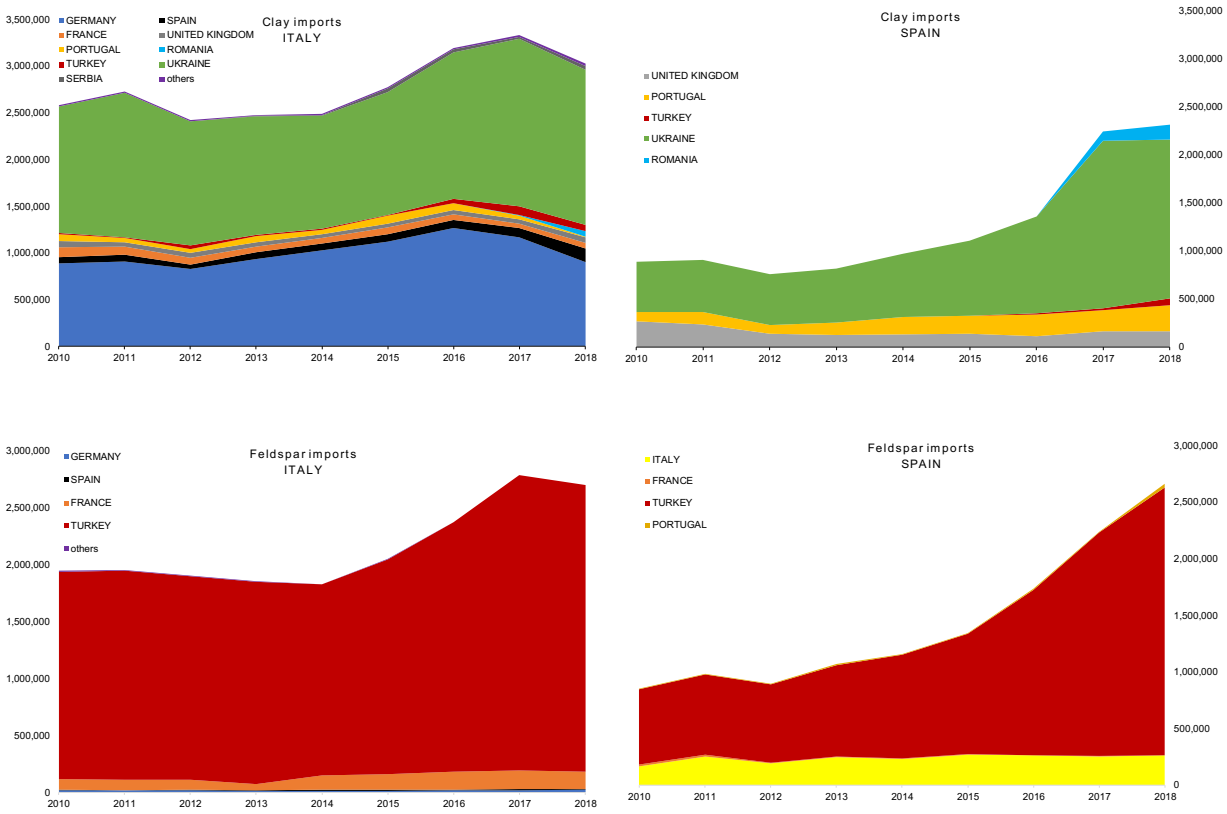

***Fig. 4**. Imports of ceramic clays and feldspar in the period 2010-2018 (tonnes) in Italy and Spain.*

The most important origin of the imported feldspar is Turkey, followed by Italy (Sardinia) and both account for more than 95% of the feldspar used in ceramic tile bodies. The use of French, German and Portuguese feldspars is practically inexistent due to the strong Turkish competition. Feldspars are used massively as fluxes in porcelain tile compositions, sometimes accounting for up to 45% of the mixture, and to a lesser extent in some white-firing wall tiles to regulate the thermal expansion. In addition, a small part of the Turkish feldspar is also used for the manufacture of frits and glazes. It is important to highlight the growth of the Turkish feldspar imports, which have accelerated since 2015 as a result of the increase in the manufacture of porcelain tiles. In 2018 the quantities imported are of the same order as the Italian ones.

Spain is an important producer of kaolin and ball clays. However, the manufacture of high whiteness bodies, mainly porcelain tiles, together with the larger size of the tiles has required the use of clays with greater whiteness and plasticity, which has led to an increase in imports of clays with these characteristics. This increase is observed from 2012 and is more pronounced from 2016. The slowdown in 2018 must be associated with the regulation of stocks, as already mentioned.

In the past, the origin of the imported clays was Great Britain and to a lesser extent France and Germany. In the period analysed, although clays from these last 2 origins were still imported, their use in the manufacture of bodies was very low, which is why they have not been included in the figures. The largest exporter of clay to Spain is Ukraine, owing to value for money with respect to other imported clays. However, in the recent years clay has begun to be imported from Portugal and more recently from Turkey and Romania, which has slightly reduced the strong dependence on Ukrainian clay for the manufacture of porcelain tiles.

Analysis of the supply chain

A preliminary assessment of possible criticalities in raw materials supply was performed by calculating the Herfindahl–Hirschman Index for the supply of feldspars and ball clays (figure 5). The degree of concentration is high, as the HHI values are always between 0.3 and 0.5, with some fluctuations in the last decade. The situation appears to be less critical for ball clays, likely because there is a second important source, together with the major supplier (Ukraine): Germany (for Sassuolo) and the domestic production (for Castellón). In addition, there is a common effort to diversify the sources of ball clay, as witnessed by further countries that have recently entered the supply chain for both Italy and Spain. With regard to feldspars, the high concentration that characterizes the Sassuolo supply chain has been matched by Castellón in the last few years: now the dependence on Turkish deposits is similar in both districts.

The incidence of the demand, summing Spain and Italy, is overwhelming on the international market, accounting for approximately 80% of imports in the European Union (figure 6). This circumstance makes the ceramic tile industry deeply influence the ball clay and feldspar market but, on the other hand, it may let policy-makers think that any problem in these supply chains is just a "ceramic tile affair".

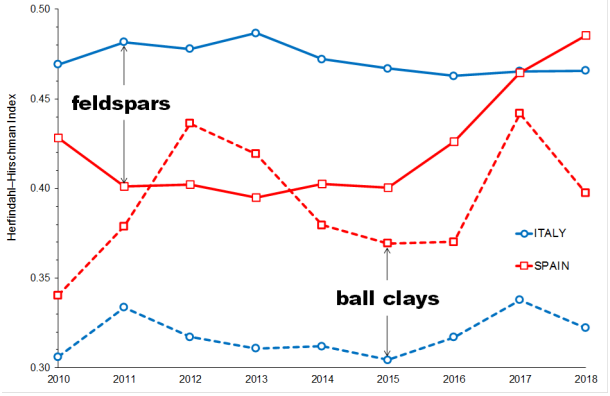

Fig. 5. *The Herfindahl–Hirschman Index calculated for ball clays and feldspars imported by the ceramic industry in Italy and Spain in the period 2010-2018.*

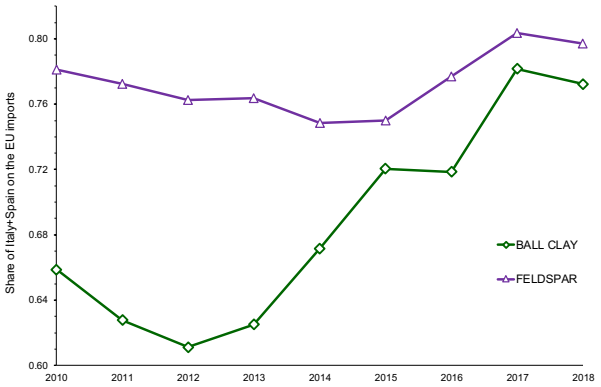

Fig. 6*. Incidence of Spain+Italy on the European market of ball clays and feldspars.*

5. CONCLUSIONS

In the last few years, ceramic tile production has been gradually changing in Spain and Italy, according to two clearly distinct strategies. Whilst Italy is even more focused on porcelain tiles, moving towards ever larger sizes and big slabs, Spain is rapidly modifying the share between red-firing bodies and white-firing bodies, with a great increase in porcelain tiles, mainly at the expense of red-firing floor tiles.

This picture has had deep repercussions on the demand for raw materials: the growing output of porcelain tiles has enhanced the demand for ball clays and feldspathic materials. Within this tendency, a strong increase has developed for special kinds of raw materials, like high plasticity clays (mostly from Ukraine) and sodium feldspar (mostly from Turkey). As far as porcelain tiles is concerned, this situation has led to increased stress on the supply chain, since both Italy and Spain rely on the same sources for 80% of their needs. Now Spain appears to be even more exposed than Italy to the access to highly plastic ball clays (Ukraine) and sodium feldspar (Turkey).

Such an increasing recourse to imported raw materials has created a strong exposure, particularly for the Sassuolo district, with import reliance up to 80%, depending on the type of raw material. Italy and Spain are competing on the same sources.

Measures to mitigate the supply risk seem to be necessary, because known reserves of highly plastic ball clays and sodium feldspars are limited, and no viable alternatives can be identified at present. In addition, the competition with non-EU tile manufacturers for the Ukrainian and Turkish raw materials is growing. This opens up lines for future research in the frame of the Circular Economy and new concept of ceramic mixes in which natural raw materials can be partially replaced by secondary ones.

6. ACKNOWLEDGEMENTS

This work was carried out within the activities of CRAM (Towards a raw materials strategy for the European ceramic industry) a Commitment of the European Innovation Partnership on Raw Materials.

7. REFERENCES

[1] Fahimnia, B., Sarkis, J., & Davarzani, H. (2015). Green supply chain management: A review and bibliometric analysis. International Journal of Production Economics, 162, 101-114.

[2] Dondi, M., Raimondo, M., & Zanelli, C. (2014). Clays and bodies for ceramic tiles: Reappraisal and technological classification. Applied Clay Science, 96, 91-109.

[3] Sánchez, E., García-Ten, J., & Regueiro, M. (2006). Materias para la industria cerámica española. Situación actual y perspectivas. Bol. Soc. Esp. Ceram, 45, 1-12.

[4] Dondi, M. (2018). Feldspathic fluxes for ceramics: Sources, production trends and technological value. Resources, Conservation and Recycling, 133, 191-205.

[5] Rambaldi, E., Carty, W. M., Tucci, A., & Esposito, L. (2007). Using waste glass as a partial flux substitution and pyroplastic deformation of a porcelain stoneware tile body. Ceramics International, 33, 727-733.

[6] Andreola, F., Barbieri, L., Lancellotti, I., Leonelli, C., & Manfredini, T. (2016). Recycling of industrial wastes in ceramic manufacturing: State of art and glass case studies. Ceramics International, 42, 13333-13338.

[7] Baraldi, L. (2018). World production and consumption of ceramic tiles. Ceramic World Review, 128, 58-72.

[8] ASCER web site | Industry | Reports and studies | Industry data: https://www.ascer.es/sectorDatos.aspx?lang=en-GB.

[9] Indagine Statistica Nazionale, ISN, Confindustria Ceramica (2006-2018).

[10] ESTACOM data base on ICEX web site: https://www.icex.es/icex/es/registro/iniciar-sesion/index.html.

[11] Eurostat data base: http://epp.eurostat.ec.europa.eu/newxtweb.

[12] Dondi, M. (1999). Clay materials for ceramic tiles from the Sassuolo District (Northern Apennines, Italy). Geology, composition and technological properties. Applied Clay Science, 15, 337-366.