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SELF-EMERGENT SUPPLY CHAIN RESILIENCE? A CASE OF INDUSTRIAL STRATEGY IN CRITICAL TIMES

Fabio GUALANDRI

Independent researcher; fabio.gualandri@gmail.com, ORCID: 0000-0001-5873-0354

Purpose: the aim of the article is to evaluate supply chain resilience strategies adopted by an industrial cluster to cope with the lack of critical materials originated from the Ukraine crisis
Design/methodology/approach: the study analyzes historical time series between the 2014 and 2022 Ukrainian crisis and assess import concentration adapting the HHI Index methodology to evaluate critical supply chains.
Findings: despite a lack of a coherent supply chain resilience strategy, empirical data imply the self-emergence of adaptive behaviors within a prototypical industrial cluster.
Originality/value: These results could suggest the intrinsic value in terms of supply chain resilience of strong socio-economic networks and addresses new research scenarios.

Keywords: supply chain resilience, Ukraine crisis, risk management, adaptability.

Category of the paper: research paper.

1. Introduction: Risk management and supply chain resilience

The military-political crisis in Ukraine, subsequent the COVID-19 pandemics, have caused massive disruption in the global supply chains: vertical industries have been hit by a sudden lack of raw materials sourced in the countries involved in the war.

These events have stressed the need to analyze the concepts of risk management and supply chain resilience (SCRes) under the light of multiple crisis. The COVID-19 pandemic, as an all-compassing calamity concerning all facets of social and economic life, has tested the resilience of global ecosystems and their ability to regenerate themselves in short timeframes.

Companies, organizations, institutions, and individuals have been forced to abruptly rethink their modus operandi to become more resilient and face unpredicted external threats.

The resilience concept, while dating back to the nineties (Horne III, 1997) was theoretically defined after the first economic shock of the XXI century: the 2008 financial crisis.

Although resilience was still a relatively undefined concept in the disciplines of risk management and supply chain management (Ponomarov et al., 2009), a plurality of definitions arose. Some focused on damage control features like survivability, adaptability and recovery in face of disruptive events or disturbances (Pettit et al., 2010; Gaonkar et al., 2007; Ponomarov et al., 2009), others included the proactive capability to predict and prevent threats at organizational level (Datta et al., 2007).

In order to face an ever changing external environment, supply chain resilience strategies, had to mold into multi-dimensional and multidisciplinary task (Datta et al., 2007; Ponomarov, Holcomb, 2009), therefore embracing also organizational resilience.

The COVID-19 outbreak has put organizational resilience at the forefront of social sciences analysis. A variety of sectors have been explored through these lenses such as the public health system (Kuzior et al., 2022), public administration (Vasylieva et al., 2020, 2021) and the digital revolution (Xie et al., 2022, Kuzior et al., 2022).

Unknown risks can be presented in a variety of forms along the supply chain: inconsistent supply and demand behaviors, natural phenomena or shifts in the geopolitical framework.

If the global supply chains were only temporarily engulfed during the peak of COVID-19 pandemics due to sanitary measures and logistics bottlenecks, the 2022 conflict in Ukraine threatens to permanently severe any supply ties between political blocks.

Russia and Ukraine lead in the extraction and first transformation process of critical raw materials such as nickel, copper, iron, neon, titanium, palladium and platinum, which are key components for advanced industries like aerospace and electronics (Ngoc et al., 2022).

Based on an impact evacuation model elaborated to assess the economical shock on Germany (Bachmann et al., 2022), the Italian central bank carried out a quantitative assessment outlining that, in case of energy disruption, Italy would have been the most damaged economy among the largest European manufacturers (Borin et al., 2022).

Several quarters of the Italian manufactory have been severely affected by the downstream ripples effect of rising commodity prices and sudden scarcity. Russia and Ukraine not only hold a significant production share in hard commodities but also soft commodities like corn, wheat, fertilizing by-products, lumber and other items serving as basic commodities for transformation industries like food processing, petrochemical, furniture manufacturing, ceramics, machinery, steelmaking, automotive.

However, it is frequently hard to properly assess the damages caused by the war or the general economic situation, since these abovementioned industries handle complex global value chains (GVC) in which inefficiencies or logistical delays are amplified by the vast amount of intermediary players dispersed in several links of the supply chain.

Anyway, if risk management literature suggests that the strength of a supply chain corresponds to the strength of its weakest process, in 2022 it can be identified as the raw material sourcing process (Bevilacqua et al., 2018).

Therefore, in order to define the boundaries of our research hypothesis and reduce the complexity, the early studies on the Ukraine's war effects choose the explanatory single-case or single-sector study as methodology to assess the industrial SCRes. (Nabhani et al., 2018).

2. Raw material imports and the case of the Italian ceramic district

The Italian tile-making industry exemplifies a supply system with high geopolitical risk and high natural resource consumption, since only a few players interact in the GVC.

This industry has been studied over the decades since it enjoy distinctive features that make it a good "laboratory" to analyze the socio-economic framework of the paradigmatic SME (Small-medium enterprise) Italian manufacturing model, due to its large size (in 2020, the overall turnover was 6.166 milion euro per 435 mln m^2 tiles produced1), geographical concentration and exemplarity as cluster (Schmitz, Nadvi, 1999).

Although limited ceramic activities scattered all over the country exist, in 2021 regional data referring to Ateco class 2007 "Ceramic floor and wall tiles" point out that, on a national scale, 93,9% export market share come from the Emilia Romagna region, where the Sassuolo ceramic district is located. (ISTAT, 2022).

Pioneering studies on tile-making industry date back to the post-war period, noting that its early success was caused by a combination of socio-economic factors and the availability of raw materials fit for ceramic tiles in the local mountains' quarries (Prodi, 1966).

A seminal survey on local economies (Porter, 1990) identified the ceramics district in Emilia Romagna region as one of the 18 "clusters", defined as geographic concentrations of interconnected companies (Porter, 2000), constituting the core of Italy's manufactory.

These local networks of small-medium companies are characterized by strong inter-company bonds, leading to multiple layers of cooperation, from knowledge transfer to shared procurement, which allow them to develop as a whole (Pyke et al., 1990).

By the new millennia the tile-making industrial district located between Modena and Reggio Emilia provinces counted the highest concentration of tile making plants in the world, accounting for approximately one-sixth of the global production. However, while local clays constituted the sole mineral source for most of its economic history, by 2000s already dropped to 40% of the demand. This trend has been mainly related with the significant commercial success of the new manufacturing process taking place in the eighties, when fast single firing and wet grinding were introduced allowing new types of tiles (Dondi, 1999).

[1] Confindustria Ceramica, 2020 National Statistical Survey on Italian Ceramic Tile Industry.

Supply diversification started in the 1990s (the same process happened in the Castellón ceramic cluster in Spain) because the clay minerals locally mined were particularly rich in iron oxide, thus giving a characteristically red hue. The growing international market requested tiles with a clear body rather than a red one, as a result the need to import clay minerals with low iron concentration became a strategic issue (Fernández-Miguel, 2022).

Sourcing new materials led to typological modifications of the final products, creating a feedback loop between the availability of raw material with specific characteristics and the emergence of new batch designs via process innovation (Dondi et al., 2021).

As a result of increased market demand the tile-making industry gradually transitioned from purely local value chains to global supply chain (GVC), a transformation that balanced higher raw material availability with mounting dependence on imports from extra-EU sources.

Further relying on imports is still a technical need since possible substitutes coming from recycled secondary raw materials still have to face technological bottlenecks in order to become enough competitive to be suited for the mass market usage (Mugoni et al., 2020).

Physical inputs from imported sources into the tile-making process are industrial minerals like clays and fluxes. Most of the Italian production consists of porcelain tiles, which requires clay as basic raw material. Porcelain products need three raw materials to made up their bodies:

1. Illitic-kaolinitic clays (ball clays), which provide the plasticity required for tile forming. Clay materials can be classified into red-firing clay, white-firing clay (ball clay) and kaolin with various degrees of chemical and mineralogical purity, depending on the industrial use (Dondi et al., 2014). In the ceramics sector they are mostly composed of the kaolinite group dioctahedral 1:1 phyllosilicates $Al_4[(OH)_8Si_4O_{10}]$, with negligible amounts of other minerals (e.g., illite) and impurities (quartz, feldspars) (Pruett, Pickering, 2006).
2. Kaolinitic clays (kaolinite 75-85%; Fe_2O_3 and TiO_2 < 0.9%) are primarily used as a ceramic raw material to produce floor tiles, tableware, glazes and sanitaryware production (Murray, 2006; Dondi et al., 2014). Other main applications are in the paper, fiberglass and cement industry, as well as catalysts, although they are not relevant for this study.
3. Sodic, potassium, or sodium-potassium feldspars, which melt during the firing process to form a glassy phase with an enough viscosity for total sintering of the product (Dondi et al., 2014).

Quartz sand offers a framework function, contrasting deformations during drying and firing processes and therefore is an indispensable constituent of silicate ceramics (Dino et al., 2021).

Nevertheless, imported materials from different countries and sources are not interchangeable: a recent study involving an expert panel consisting of twenty-one top and middle-management position within the Italian ceramic industry determined that on a scale of 1 to 5 ((1) extremely low, (2) low, (3) medium, (4) high, and (5) very high), only the Ukrainian

ball clays were pointed to have a very high (5) level of criticality, due to their high-plasticity (Fernández-Miguel et al., 2022).

The main alternative to Ukrainian imports are the German medium-plasticity ball clay and the Turkish sodium feldspar clays. Furthermore since the technical features are different, the manufacturing process has to be adapted too.

German clays are not as plastic as the Ukrainian type, impacting the final product quality. Alternative extraction of low-plasticity kaolinitic clay from Italian quarries would pose even greater manufacturing issues (Fernández-Miguel et al., 2022).

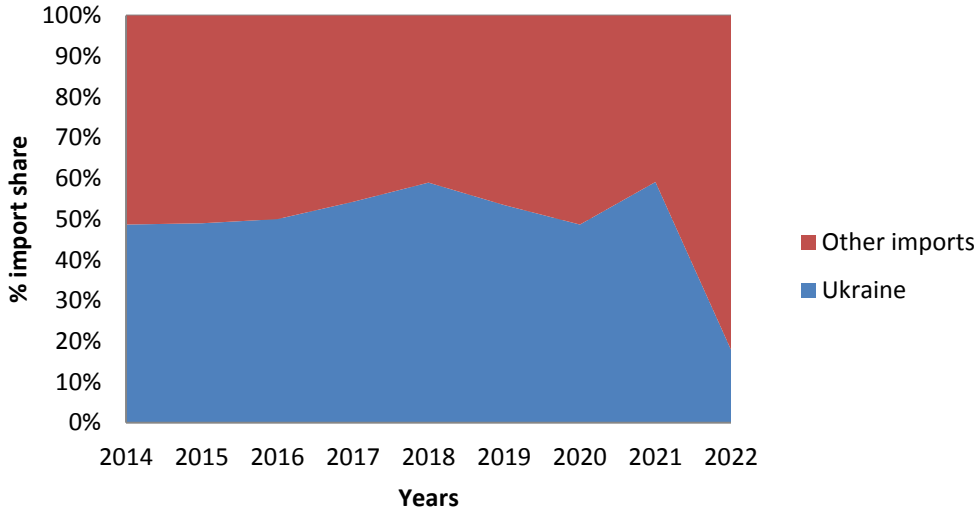

Figure 1. Historical data on import share % Ukraine vs. other import countries.
Source: Italian Institute of Statistics SH4 2508.

The industry has historically been depending on a singular critical source, the Ukrainian quarries, as shown in the figure 1, producing around half of the Italian imports.

In such energy and commodity-intensive manufacturing business, any supply disruption can severely endanger the stability of the industrial production, thus supply chain resilience plans are posed to have paramount importance in production management.

Risks are potentially predictable based on historical information. Multiple commodity price shock and geopolitical crisis have contributed to the heightened awareness that dependence on limited sources located in unstable regions is critical (Fahimnia et al., 2015).

Following the war hostilities in Eastern Ukraine the clay and feldspars supply extracted from quarries in the Donbass region were suddenly broken down in the first half of 2022.

The customary logistic route looked as follows: extraction in Donbass quarries, shipping from the port of Mariupol in south-eastern Ukraine to the Ravenna port in north-east Italy and transfer by truck to the ceramic district around Sassuolo, Emilia Romagna.

The conflict in Ukraine in 2022 can hardly be considered a “black swan” (Taleb, 2009) phenomenon from a risk management perspective, since the crisis dates back to 2014.

However, the geopolitical risks has not been considered and recent qualitative survey (Fernández-Miguel et al., 2022) assessed that any coherent plan was adopted to mitigate the risks of a sudden supply disruption. The intent of this work is verify these assumptions and the level of supply chain resilience in this critical time.

3. Database & methodology

In spite of its significance for the ceramic tile industry risk management, there is not an raw material database available, due to the complex structure of the European ceramic industry determining that the data ownership belongs to individual companies (Dondi et al., 2021).

To surmount these barriers, the data have to be extracted by the monthly reports on Foreign Trade section (COEWEB) of the Italian Statistical Institute (ISTAT) related to inter-country trade between Italy and the world, namely on the specific database "Volume trade by product area and country: SH4 2508 [Clays, andalusite, kyanite, sillimanite, whether or not calcined; mullite, chamotte or dinas earths (excluding kaolin and other kaolinic clays)] – January-September 2022" which encompasses most of clay materials imported into Italy.

Since there is no statistical indicator available in literature, which clearly define the supply chain diversification, the author considered repurposing the Herfindahl–Hirschman Index (HHI) to measure import diversification, based on previous literature about the effects of export concentration on developing countries' economies during economic crisis (Camanho da Costa Neto, Romeu, 2011).

HHI is a method for measuring market concentration which is widely used by public regulators in competition law to measure the single company market share in order to evaluate M&A acquisition from an antitrust standpoint.

The HHI takes into account the relative size and distribution of the firms in a market and approaches zero when a market consists of a large number of firms of relatively equal size. The HHI increases both as the number of firms in the market decreases and as the disparity in size between those firms increases.

It is calculated by squaring the market share of each firm competing in the market and then summing the resulting numbers. If there is only one firm in the market it means 100% market share. In this case the HHI would equal 10 000, indicative of a monopoly.

To measure the production concentration of a critical commodity the authoritative report World Mining transpose the firm HHI, although states that there is not a global consensus at which level concentration becomes critical (World Mining Data, 2022).

In the United States, between 1000 and 1800 points is considered to be acceptably concentrated, data in which the HHI is in excess of 1800 points are considered to be concentrated, while the threshold for concentrated markets in the European Union is 2000.

The repurposing of the HHI for this paper focus on the share of imports of the critical materials significantly exported by Ukraine or the Russian Federation and used a particular industry, as defined by the HS4 code in the international classification of goods.

The concentration of producer countries is calculated by the HHI similarly to the firms index. To avoid misunderstandings with the "classical" HHI, the countries concentration index is named as HHI(ct). Hence this index essentially measures the inequality between the shares of imports.

The HHI is defined as: subscript *n* in equation:

$$HHI(ct)= \sum n=N*sn2$$

where:

n indicates the trading partner,

N indicates the total number of trading partners,

sn is the imports value share sourced from the *n*th trading partner.

$$Sn = (s1,2,3 \ldots *100)/ \sum Sn$$

A higher value of the HHI indicate a lower import diversification, tending to cause supply chain bottlenecks, and vice versa a lower value of the HHI is a sign of higher import diversification. The dataset is limited to countries who have exported the selected goods to Italy in the 2022 survey. Values less than 1% of overall import on a year by year basis are deemed irrelevant and not considered in the statistics.

4. Supply chain disruption and adaptation

As a first step the study should assess if a general disruption in the overall flow of clays from imported sources, which constitutes the bulk of raw materials used by tile-makers in the industrial districts as assessed in section 2, has taken place.

Following this consideration, an hypothesis where the sharp decline of Ukrainian production in 2022 as the main global import source (see figure 1) has impacted the global import trend in 2020-2022 can be formulated.

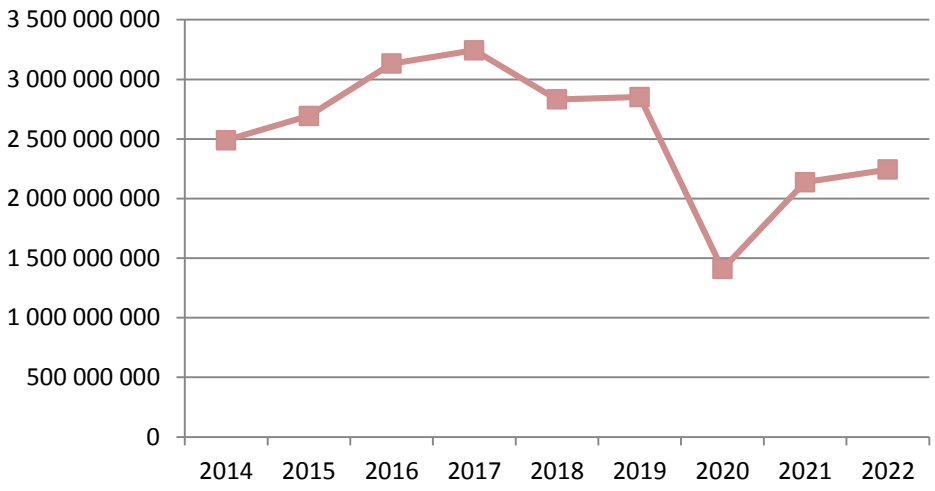

Figure 2. Global clay import in Italy in kg.

Source: Italian Institute of Statistics SH4 2508.

On the contrary, such an hypothesis is not backed by data yet. In fact, Figure 2 shows that the 2020-2022 timeframe has seen a bounce back in imported clays, whose figures have not reached the pre COVID situation, but the overall import trend is increased imports, although the curve is flattening and reaching a stabilizing point at just over 2 mln kg.

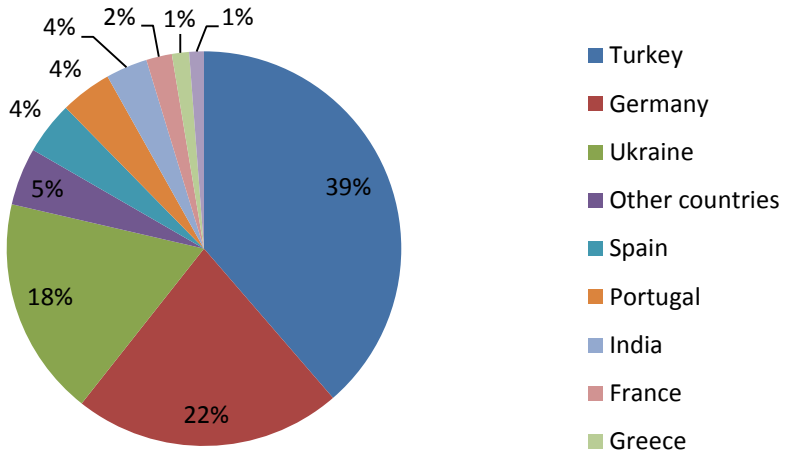

Figure 3. Global import suppliers' share 2022.

Source: Italian Institute of Statistics SH4 2508.

Thereby the 2022 clay supply scenario is displayed in figure 3. Turkey has become the primary import source, followed by Ukraine and Germany, while minor exporters provide around 22% import share. In order to evaluate the industry supply resilience, these data should be put into historical perspective, comparing statistical time series from 2014, when the first Ukraine crisis occurred up until 2022, when the Russo-Ukrainian war broke out.

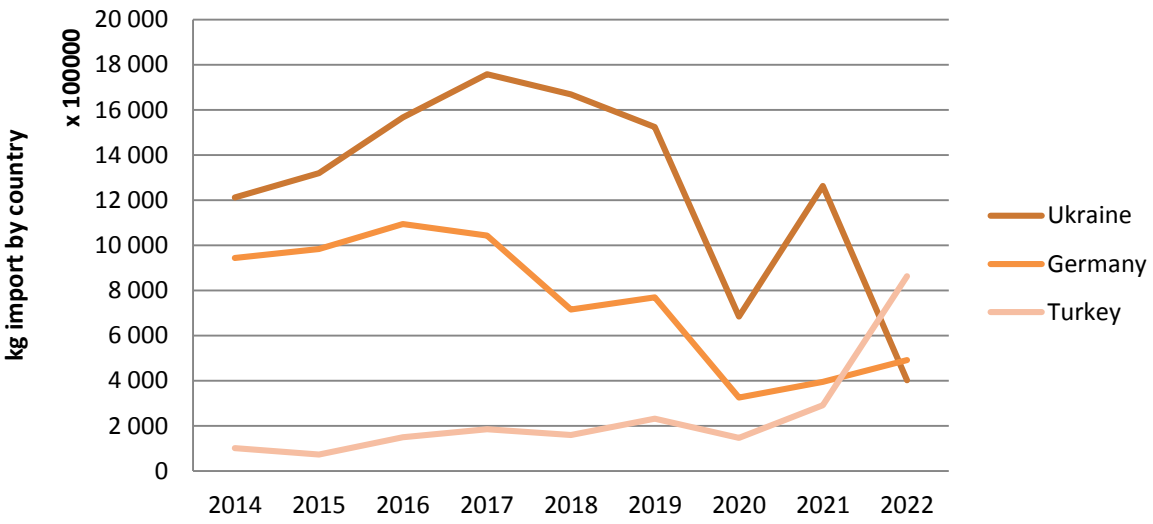

Figure 4. First-tier clay suppliers to Italy 2014-2022 years.

Source: Italian Institute of Statistics SH4 2508.

First-tier suppliers of the Italian industry are regrouped in figure 4: Ukraine, Germany and Turkey. While Germany has been consistently the second clay supplier, Turkey took over its position in 2021. Notwithstanding the military crisis in Donbass started in 2014, imports from Ukraine peaked in 2017, followed by a consistent import declined (with exception in 2021).

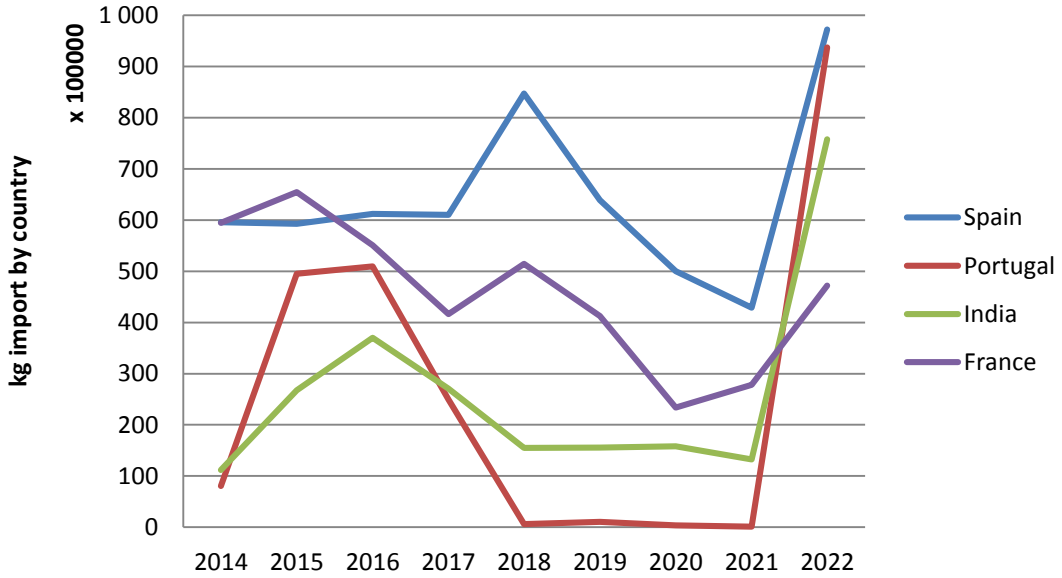

Figure 5. Second-tier clay suppliers to Italy 2014-2022.

Source: Italian institute of statistics SH4 2508.

Second-tier suppliers (between the 1 mln kg and 400 thousand kg) can be grouped into two different categories: stable suppliers and late-coming suppliers. Spain and France belong to the first category as stable import source, reaching a peak in 2018 and then declined.

India and Portugal have been introduced in the supply mix only after the 2014 crisis in Donbass and afterwards reduced their market share. However, both suppliers drastically increased the export to the Italian manufacturers in 2022 after the war in Ukraine broke out.

While previous analysis stated a strategic dependence solely on Turkish imports (Dondi et al., 2021), this statement is only partially confirmed, since it is reduced by the sudden surge of imports from previously second-tier sources such as Portugal, India, France and Spain.

Even though any coherent SCRes strategy has been laid out, data substantiate a swift and effective import substitution policy of Ukrainian production in 2022 combined with a path towards diversification by activating low-volume import channels.

In order to validate this assessment figure 6 visualize the yearly HHI import concentration index which has been calculated, with a linear regression showing a consistent trend in place.

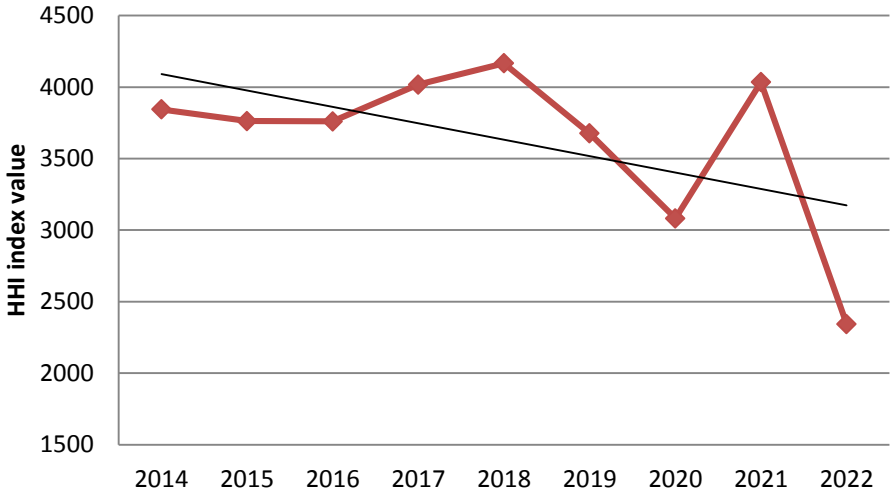

Figure 6. HHI index value 2014-2022.

Source: author's own study based upon Italian institute of statistics SH4 2508.

The HHI index lowers from a peak of 4166 in year 2018 to 2342 in year 2022, getting closer to the European Union threshold for competitive market.

Except of 2021, which can be considered an outlier since it was heavily influenced by logistical struggles during the COVID-19 pandemics, a pattern towards reduced dependence take place from 2018 onwards, as can be seen in the linear regression.

5. Conclusion

Supply chain and risk management best practices suggest to take an integrated approach with the goal of controlling risk exposure and reducing its negative impact on SC performance. (Heckmann et al. 2015), but in real life situations organizational issues often hamper the elaboration and, most importantly, the execution of SCRes strategies.

This occurrence might happen, from a sociological viewpoint, because social groups, companies or individuals develop different risk acceptability levels in different risk situations, as well as reactions to each of these circumstances.

In real world context these risk evaluations are guided by socio-economic factors, informal networking and cross-corporate culture, rather than a scientific probability estimation based on business intelligence. Thus, the objective risk analysis can be altered by the different risk perception among different decision-makers (Gordy, 2016).

Given the enduring flux of commodities from Ukraine after the conflict outbreak, reaching a peak in 2017, might have provoked excessive confidence in the industry decision-makers about the middle-term stability of this supply stream. This optimism bias could have been enhanced by the cognitive and economic costs to find a viable alternative solution to Ukrainian clay, which should have been considered higher expenses and lowered quality.

Thus, the social network binding Italian tile-making companies allows to formulate an hypothesis of informal cross-company information exchange that could have driven the progressive source diversification since 2018 and ease the swift supply adjustment in 2022.

Although the recognition of outside threats requires an organized supply chain resilience plan to enforce pre-emptive actions, the study's findings may suggest that the capacity to adjust to disruptive scenarios can be enhanced by a strong social interconnection.

In January 2023, many statistical data upon the consequences of the Ukrainian war are not yet available, further qualitative investigation should be carried out on the field to verify if the patterns emerging in data were part of a coordinated plan or they were self-emerging.

Theoretical tools like the Complex Adaptive Systems (CAS) theory, which has been proposed as a framework to study SCRes (Tukamuhabwa, 2015), might be interesting to implement to analyze the style and the features of the decision-making leading to generate, strategically or spontaneously, the reaction to external shocks. The collective social behavior of economic clusters feature typical CAS characteristics like adaptability, self-organization and emergence and it could suggest a future research direction.

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