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An evolutionary analysis of industrial districts: The changing multiplicity of production know-how nuclei

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This paper deals with the evolution of place-based division of labour, considering in particular the dynamics of differentiated pools of knowledge that can be embedded in local production systems such as industrial districts. Drawing on conceptual framework of Marshallian industrial districts, the paper develops a model that links knowledge dynamics to possible tendencies towards either industrial progress, lock-in, transition, or decline of such systems. The model is complemented by a related new statistical method that allows to analyse the evolution of the multiplicity of production know-how nuclei inside industrial districts. The methodology is applied to two cases: the ceramic district of Stoke-on-Trent (U.K.) and the textile district of Prato (ITA) over the period 2005-2013.

Keywords: Industrial District, Productive Knowledge, Local Change, Prato textile district, Stoke-on-Trent ceramics district
JEL classifications: R12, L61, L67

1. INTRODUCTION

The prosperity of nations can be shaped by the organisation and development of their factors endowment, which can support or damage positions of industrial leadership by promoting or weakening the accumulated capabilities that drive the competitive advantages of the industrial division of labour. This line of thinking has run through the work of Adam Smith and Alfred Marshall, and more recently of Allyn Young, Jane Jacobs, Giacomo Becattini and Michael Porter. The latter have focused respectively on cities, industrial districts and clusters where economic activities unfold. Although different, they tend to pool professional, moral, and creative capabilities of groups of people that are intertwined with the destiny of evolving agglomerations of specialised businesses. These are wired in a much larger interconnected world that Adam Smith called "the extent of the market" and Marshall "the civilised world".

The paper is part of a wider debate in regional studies on the long-term evolution of place-based systems of localised knowledge and collective learning (see Antonelli, 1999; Boschma, 2005; Cusmano et al., 2014; Kemeny and Storper, 2015). Industrial districts (IDs) are examples of such systems, since they embody a complex set of endowments and processes[1] able to sustain self-renewing innovation, but also to lead to path-dependency and lock-in conditions (e.g. Grabher, 1993; Staber, 2001; Martin, 2010).

Drawing on the neo-Marshallian tradition of IDs' studies (Becattini, 1989; Bellandi, 1989), this paper presents a novel way to explain how changes in the endogenous accumulation of a differentiated pool of knowledge inside industrial districts can inform their evolutionary trajectory. We present first a conceptual model whereby IDs' paths of change are characterised by variations in the multiplicity of nuclei of production know-how rooted in the place.

The model is then applied to two historical IDs: the textile district of Prato (Italy) and the ceramic district of Stoke-on-Trent (UK). The long-lasting embeddedness of the main manufacturing industry into their respective social fabric enables us to make some longitudinal comparison, necessarily taking into account variations in productive specialization and national contexts. Specifically, in the pottery industry in Stoke the core manufacturing process is less decomposable than in the textile industry in Prato because of technological and historical reasons. This may lead to structural variations in the organisation of these sectors in specific places. Indeed, we are concerned with understanding their evolutionary trajectories by exploring the interplay between the main industry and the related or unrelated secondary industries. The comparative analysis presented here allows us to apply the conceptual framework and the novel empirical methodology to such cases as examples.

The paper proceeds as follows: Section 2 introduces the concepts of multiplicity of know-how nuclei and the conceptual model. Section 3 illustrates the empirical methodology. Sections 4 and 5 present a historical overview of the two districts and discuss the findings from the application of the methodology to them. Aware of the limitations that such comparison might have, we end with some cautions final remarks.

2. LOCAL DIVISION OF LABOUR AND MULTIPLICITY OF KNOW-HOW NUCLEI

We draw on the definition, the 'Marshallian industrial district' as "a localised 'thickening' (and its strength and weakness both lie in this spatial limitation) of inter-industrial relationships which is reasonable stable over time. Its composite nature, tending towards the multi-sectorial, gives it, even in the midst of intense change, a stability which a unit such as a single industry, in the technological sense of the term, lacks: it is therefore possible to study

it, in order to ascertain its permanent characteristics, the 'laws' which govern its formation, its maintenance and its decline." (Becattini, 1989, p. 132).

Local firms are connected by way of both market and non-market mechanisms, such as a local nexus of institutions and social norms, and specific public goods. These mechanisms emerge from high levels of cultural and cognitive proximities that are essential to strengthen network relationships, decrease transaction costs at a local level and foster Marshallian external economies in terms of adaptability and productivity (see Wilkinson, 1983; Bellandi, 1996).[2] The sets of skills and business capabilities are reproduced thanks to shared attitudes at the local level, as well as thanks to specific mechanisms of learning-by-doing, using and interacting across the specialised activities.[3] Innovations, especially incremental innovations, tend to result from applications of a rich set of original approaches to the limited field of business and production activities. At the same time, more original innovations draw on creative combinations of the multiplicity of specialised nuclei of know-how, run each by a plurality of teams of entrepreneurs and skilled collaborators. Here, mutual understanding is facilitated by the opportunities offered by the exchanging of intermediate products and service, as well as by the local overlap of life experiences (educational, working, family, social) (De Propris, 2002). Such innovations can be fruitfully applied to raise production efficiency and the customisation of products and services to local and external markets. Some innovations may also have the unanticipated positive effects of adding new know-how nuclei to the district, thereby enlarging its inner structural multiplicity, and opening further market opportunities for local specialised firms.

The single nucleus of specialised know-how refers to a field of specialised activity relatively homogenous in terms of productive and organizational knowledge. The multiplicity of nuclei is not only related to the manufacturing core of the district, but also to the provision of raw materials, services and other activities complementary or related to the manufacturing

core (Bellandi, 1996; Frenken et al., 2007), as well as all to the variety of secondary activities in place. Indeed, all know-how nuclei shape the contours and the grains of an ID's specialisation beyond the narrow sectoral definitions, identifying the main cognitive structure of the district; over time, also secondary nuclei can play a role in the evolution of the ID.

The evolutionary paths of change available to an ID depend on this cognitive structure, and on its institutional structure that include the set of agents and mechanisms impinging on collective semi-automatic or constructive actions of cooperation (Dei Ottati, 2009). Specifically, strong local institutions support differential incentives and coordination platforms for the dynamics of know-how nuclei; but institutional stability may also cause rents-seeking and inertial behaviour and erect barriers to technological change (Grahber, 1993; Mistri, 2009). Indeed, the dialectics between cognitive and institutional components shape the ability of the district to meet exogenous challenges by activating a process of *decentralised industrial creativity*. The latter is the creation of new knowledge from fruitful exchanges of goods and ideas across a large number of firms; and such new knowledge enters the innovation process (Bellandi, 2003).

Depending on how the multiplicity of know-how nuclei evolves, and how the institutional structure adjusts to this evolution, the system might be led to a lock-in outcome or it might embark on a renewal path. In this sense, contributions that have looked at ID as 'mono-centric' production systems (strictly and narrowly mono-sectoral) are inconsistent with evidence rather pointing to the existence of IDs with 'polycentric' structures and processes (Becattini, 1989). The types and degrees of polycentrism accounts for the variegated spectrum of performance of Italian IDs have experienced (Belussi and De Propris, 2013).

FIGURE 1

We would argue that when new know-how nuclei emerge within an ID, then '*structural holes'* appear in the fabric of cognitive relations connecting the ID's division of labour (Burt, 2000). Such holes could be used by the entrepreneurial community in the ID to identify and explore new opportunities for cooperation over production linked to creative problem-solving. When this happens regularly, thanks also to a supportive institutional structure, the cognitive structure of the district grows, and the ID moves along a "quasi-steady state" path of development.[4] We summarise this in Figure 1 where the growth of the cognitive structure (CS) is captured by $CS_t < CS_{t+1.}$

When the core is hit by a crisis or by some enduring competitive or social challenges, the polycentric structure may act as a "*substitutive multiplicity*" (Bellandi, 1996). Here, some secondary nuclei can support local income and employment in the short run, or may help trigger a new development trajectory characterised by either a new specialisation or a combination of new and old specialisations crossing along the statistical sectoral classifications.

The preservation of a high degree of sector concentration in the core during a deep crisis may be the sign of a serious entrapment in lock-in conditions. Equally, the presence of growing secondary specialisations technologically and cognitively distant from the traditional ones is not necessarily the basis for a new development path. This is because, either the entrepreneurial forces fail to grasp the new opportunities, or the institutional structure fails to create incentives stimulating fruitful cognitive interactions between nuclei internal and external to the traditional core. In this case, the ID's traditional core is locked in a persistent configuration whereby its cognitive structure is stationary ($CS_t = CS_{t+1}$). Such *cognitive* and *institutional traps* can be fatal. IDs' performance is destined to decline as innovative combinations are exhausted, whilst external competition erodes its competitive advantage. In

the end, the failure to avoid either traps will reduce the nuclei multiplicity ($CS_t > CS_{t+1}$) making the ID shrivel as an organised and complex system of production.

It is not easy to translate such conceptual background into a robust empirical analysis, even if some of its premises are easily found at the basis of the evolutionary discourse flowing along in-depth case studies (Becattini, 2004; Mistri, 2009).

To understand the evolution of a district's production structure, localised 'multiplicity' needs to be tracked over time. In next Section 3, we propose a methodology comprising three components: 1) identification of the multiplicity of all the 'know-how nuclei' (n); 2) longitudinal analysis of the multiplicity; 3) analysis of the variation in structural characteristics of multiplicity. In Section 5 we apply this to two cases introduced in Section 4, i.e. the Stoke-on-Trent district and the Prato district.

3. A METHODOLOGY FOR THE INVESTIGATION OF CHANGES IN MULTIPLICITY

Within each district for any given period, each know-how nucleus mirrors a specialised activity that is relatively homogenous in terms of knowledge, practices, and actors, but relatively dissimilar to other activities. A comprehensive map of such activities requires an in-depth data collection where the unit of analysis is the place with its multitude of business activities, some related to the industrial core and some not. Following Santini (2016), we adopt a quantitative methodology to map out the multiplicity of the know-how nuclei (n) characterising all the firms comprised in the district (M) at any point in time (t) – such as annually.

Specifically, the first step is to construct a large dataset with information about each firm (u), with $u \in M$. Such information is meant to relate to or capture differences in knowledge,

practices and subjective features across firms (e.g. concerning the entrepreneur). It is reasonable to assume that firms' sector and size (in terms of employment and or assets or turnover) are basic indicators of cognitive similarity or dissimilarity. The sector variable captures cognitive similarity to the extent that it can be measured by looking at firms' statistical codes within the hierarchical structure of standard sector classifications. While size helps draw a quite coarse picture of the ID business configuration and of the organizational knowledge embodied in the firm. IDs tend to be populated by small and medium sized firms. We assume therefore that the presence of a large firm associated with a given sector code is enough to identify a separate know-how nucleus; whereas, the presence of smaller firms requires a critical mass of them to form a separate nucleus in correspondence with a single sectoral code.

The second step consists of a cluster analysis applied to the above firm level dataset, to identify discrete groups of firms showing a high degree of similarity (Rong et al., 2015).[5] These sub-sets of $u \in M$ will be cognitively homogeneous and will represent the production know-how nuclei of the district.

The two-step methodology applied at the district level over time enables us to observe variations in the number (*n*) and the type of know-how nuclei.

We distinguish situations where one can observe the number of know-how nuclei increase ($\dot{n} > 0$), shrink ($\dot{n} < 0$), or again remain stable ($\dot{n} = 0$). We would maintain that $\dot{n}$ captures the variation of multiplicity over time, and we call it the *multiplicity variation index*.

Another important feature that helps understand the evolution of an ID concerns the distribution of the population of the firms across the different nuclei. An extreme form of ideal-typical ID sees a strong concentration of SMEs in a set of core nuclei included in one restricted sectoral field, and a thin dispersion of the remaining firms in nuclei representing

peripheral sectors. Instead polycentric forms of IDs are characterised by less concentration and by the presence of various know-how nuclei grouping firms in different sectoral fields.

To measure the levels of concentration of firms around the *n* nuclei, we adopt a Shannon Entropy index, which reduces the effect of the weight of the bigger firms on the overall measure (e.g. Jacquemin et al., 1979). The entropy index is an inverse measure of concentration and can be written as follows:

$$En = \sum_{c=1}^{n} [P(c) * log \frac{1}{P(c)}]$$

where $c \subset M$, and *n* denotes the total number of know-how nuclei; *P(c)* measures the number of firms in each nucleus *c*. With this index, variations over time in the concentration of firms are influenced by the variation of the total number *n*. Therefore, we normalise the index by dividing the entropy index by its maximum level (*ln n*) for each period (Santini, 2016):

$$E_0 = \frac{En_t}{\ln n}$$

Here, $\dot{E}_0$ indicates the variation in the relative entropy index over time. We call it the normalized *entropy variation index*. Recall that as entropy increases, the degree of concentration of the firms within the nuclei decreases, and vice-versa.

We maintain that the **multiplicity variation index** ṅ and the **entropy variation index** $\dot{E}_0$ provide crucial information to understand an ID's inner capabilities and dynamics, and their influence on its evolutionary course – development, crisis, renewal, and transition. Considering combinations of the two indexes as positive, negative or stable produces a matrix with nine possible entries (see Table 1).

TABLE 1

Indeed, the nine combinations suggest different scenarios reflecting different stages of an ID evolution (see Table 2). Such inferences demand conditions of relative stability in relation to the number of nuclei, the number of firms, and employment, as in the two case studies

discussed in the next Sections. Complementary meta-analysis of qualitative information on individual cases studies is in any case necessary and desirable to draw rounded and realistic interpretations of the findings.

TABLE 2

At birth the district tends to be marked by an increasing concentration of resources within few specialised sectors ($\dot{E}_0 < 0$) together with a stable set of different nuclei ($\dot{n} = 0$). This corresponds to state 4. The combination of an increasing number of know-how nuclei ($\dot{n} > 0$) and a non-decreasing structural concentration corresponds to a phase when the district sees its core specialisations strengthening. This means greater concentration ($\dot{E}_0 < 0$) or preservation of the core ($\dot{E}_0 = 0$) together with a larger multiplicity of nuclei. State 1 corresponds to rapid growth or renewal, while state 2 (organic development) is what in the district literature is referred as an ID in "working order" of development (Becattini, 2004, p. 29; Dei Ottati, 1994b).

Instead, a shrinking of the relative concentration ($\dot{\mathrm{E}}_0 > 0$) and an increase in the number of know-how nuclei (state 3) may signal a tendency towards a more polycentric path of development. This would suggest changes in the core of the district, indicating a renewal or instead a transformation leading to a different model of development.

A reduction in the number of know-how nuclei is consistent with several possible outcomes. An increasing concentration points to conditions of rationalization, whereby the resources of the district converge to ensure the survival of the main specialization, plausibly the traditional one (state 7). This increases the loss of adaptability and the risk of lock-in. When both the number of know-how nuclei and the relative concentration decrease, the ID is likely to find itself already locked in a deep crisis, marked by the inability to renew its production structure and preserve its know-how basis, plunging the district in irreversible decline (state 9).[6]

4. THE CASESOF TWO MATURE INDUSTRIAL DISTRICTS

The conceptual framework above presented is tested with an application to two historical industrial districts, one in Italy, the textile district in Prato, and one in the UK, the ceramic tableware district in Stoke-on-Trent (Santini, 2016). We realise these are very different districts, born and evolved along different trajectories, not least rooted in different economic, social and cultural locales. Nevertheless, the fact that they have been industrial districts over time allows us to attempt a meaningful comparison.

We will look at the years 2005-2013. This is a period of great interest, since it starts during a phase of international economic growth interrupted by the great financial and economic crisis. Started in 2007-2008 it has led to a long stagnation in many countries, especially in Europe. In this Section, we shortly introduce the two districts before moving on to the empirical analysis on section 5.

4.1 Stoke-on-Trent and the Potteries

'The Potteries', the name traditionally used to identify the ceramic tableware district of Stoke-on-Trent in North Staffordshire (Popp and Wilson, 2009), was firmly established by the mid-nineteenth century but the commercial production dates back to at least the late XVII century. This is one of the oldest UK industrial districts where there is still production and some historical firms. The Potteries is comprised within six contiguous townships, Tunstall, Burslem, Hanley, Stoke, Fenton and Longton (Popp, 2001).

The basis of natural resource endowments (coals and clays) and the important canal network linking it to Liverpool and Manchester were the main reasons for its take-off during the Industrial Revolution. The district grew and expanded thanks to: a) attraction and concentration of specialised labour; b) growth of auxiliary sectors; c) links with important sources of raw material and mercantile networks; d) the emergence of locally embedded

circuits of credit and finance; e) the strengthening of institutional and collective actions providing specific support to the local industry. In particular, "*the growth and development of a population of auxiliary firms in the Potteries led to the creation of a tightly clustered system of disintegrated production, yielding external economies of scale, economies of flexibility, and reduced risks*" (Popp, 2001, p. 228).

In the 1960s and 1970s, a relative technological stability and the emergence of foreign competitors put under severe pressure the competitive structure of the local industry. A small set of large integrated firms[7], which had started already to grow with the implementation of the Clean Air Act (1956)[8], gained a dominant position in the district. The recession of the early 1980s and the offshoring of manufacturing functions to low cost economies in the 1990s and the early 2000s led to greater business concentration in the hand of a few big companies[9] and to a reduction in the number of jobs and firms. Ultimately, the ceramics industry shrank approximately from 52,700 employees in 1979 to 7,200 in 2008[10], while the employment levels since 2011 seem to have been relatively stable. According to some studies, the historical district seemed to have almost disappeared slipping down a path of slow and "long decline" in the early 2000 (Popp, 2001). However, more recently, there have been signs of recovery with 'green shoots' of local industrial competences and knowledge being translated in new products and businesses.[11] In a sense, the 'Marshallian atmosphere' would be still active (Tomlinson and Jackson, 2013, p. 609) and able to generate entrepreneurial vitality.

4.2 The textile district of Prato

The textile district of Prato is recognised not only as one of main Italian industrial districts but also as an archetypal example of Marshallian industrial district (Becattini, 2001). It is located in the Italian region of Tuscany and currently stretches across twelve contiguous

municipalities: Prato, Cantagallo, Carmignano, Montemurlo, Poggio a Caiano, Vaiano, Vernio, Agliana, Montale, Quarrata, Calenzano and Campi Bisenzio (Becattini, 2001). The local textile industry has a long history that dates back to the Middle Ages. Before the Second World War and in the immediate post-war recovery period, Prato was characterised by two parallel circuits of firms: one of vertically integrated firms producing a few types of carded woollen fabrics in long series for national and international markets; and a secondary circuit comprising small craft producers (Dei Ottati, 1994b).

In the mid-1950s, a very important change was the introduction of the nylon fibre inside yarns for carded wool. This innovation expanded the range of products and allowed to meet a growing demand for variety from the 1960s onwards. Changes in technology and demand led to a breakdown of vertically integration lines replaced by local phase markets among firms specialised in single or a few stages of the production process (Dei Ottati, 1994b). Local phase markets were integrated both by collective action on contractual norms and territorial and technical infrastructures and by the action of 'open teams of specialised businesses' (see the section on flexible integration in chapter 2 of Becattini, 2001). Between the 1970s and the 1980s, firms started to work with many different fibres expanding production across an ever more differentiated range of yarns and fabric. Various complementary and related productions emerged locally, such as machinery, tools and dyes for the textile industry, clothing, and – later – ICT.

At the turn of the 21st century, several shocks damaged the district. Low cost competitors from Asia in the yarns and fabrics markets undermined its domestic and international position, hitting local production and the related system of local firms and jobs. On the other hand, trickling since the 1990 and gathering pace more recently, an inflow of Chinese migrants led to the emergence of a parallel clothing and knitwear cluster of activities in Prato, centred around Chinese entrepreneurs and labour, and with weak relations with the historical

textile district (Dei Ottati, 2014; Lazzeretti and Capone, 2017). After the 2008 crisis, the clothing and knitwear activities revolving around the Chinese community has provided a source of economic stability to the city, but has also unleashed racial and social tensions heavily threatening the social cohesion of the district – still leaving uncertain where this would lead to (Lombardi and Sforzi, 2016). Dei Ottati (2014) maintains that the 'two different communities' of the Prato textile district have not been able to take advantage of each other's resources.

5. APPLICATION OF THE MULTIPLICITY METHODOLOGY TO THE TWO CASES

We apply now the methodology to identify and analyse the evolution of multiplicity in the two cases above described. To calculate the know-how nuclei in the two districts and map their evolution over the period 2005-2013, we use two datasets (Santini, 2016). For both districts, we consider their functional economic areas that statistically are by travel-to-work-areas as geographical unit of analysis.[12] Stoke-on-Trent data is extracted from the FAME archive for Stoke-on-Trent with a four-digit sector classification; while for Prato, data relies on the AIDA database, with a five-digit sector classification. The European classification of small, medium and large firms is also applied. Moreover, in the case of ID Prato the entrepreneur's nationality was one of the considered variables.

5.1. Quantitative analysis

For both districts, we counted all firms – across all sectors – listed in the respective databases over the period 2005-13. In Stoke-on-Trent, we counted 4,134 productive units in 2005 and 9,819 units in 2013 (an increase of 135%). Moreover, the absolute value of big firms increased over the period in Stoke-on-Trent, but the relative share decreased from 2%

to 1.4%. In Prato, we found 6,621 productive units in 2005 and 9,519 in 2013 (an increase of 43%). In the Prato case, medium and large firms together accounted for 1.3% of the total in 2005 and only 0.85% in 2013. Chinese firms grew from around 0.50% of the total in 2005 to 1.25% in 2013.

By means of a cluster analysis applied to both districts, we group firms in know-how nuclei (*n*). The number of nuclei grew from 2005 to 2013 in both IDs, namely $\dot{n} > 0$, with the number of nuclei growing from 484 to 579 in Stoke, and from 567 to 706 in Prato. This can be explained in several ways, including for example, in the case of Stoke-on-Trent, the location of a new large firm or the emergence of a new agglomeration of smaller firms producing in a new sectoral field. In Prato, the number of nuclei has risen for similar reasons, as well as for the emergence of the new parallel nuclei of Chinese businesses, in traditional (i.e. clothing) and newer fields (i.e. business services) of sectoral activity and with similar firm size. Stoke-on-Trent registered a mild reduction in the number of nuclei in 2006 and 2008, that is just before and at the beginning of the US subprime mortgage crisis; afterwards the district was able to recover with a rising number of know-how nuclei especially after 2011. Prato is marked by a more volatile trend, registering substantial downturns in the number of nuclei in 2008 and between 2011 and 2012, while the periods 2009-2010 and after 2012 indicate some recovery. It is worth reminding that Italy was in a period of recession in 2011. The volatility of number of nuclei in Prato, with its highly variegated entrepreneurial structure, could be signalling either flexibility or a passive adaptation to exogenous shocks.

Apart from some similarity in the general trend, the evolutions of the two IDs reveal some important differences in the number of nuclei (n) represented in the y axis over time (see Figure 2).

FIGURE 2

We calculate the entropy index for both districts to shed light on changes in their internal know-how nuclei composition − please bear in mind that entropy is an inverse measure of concentration (see Figure 3). In Stoke-on-Trent, we find that entropy drops steadily over time suggesting an increase in the level of economic concentration in fewer yet populated nuclei. Whereas, in Prato entropy rises steadily marking an economic diversification of the productive structure, perhaps with some acceleration during economic downturn.

FIGURE 3

Over period 2005-2013, Stoke-on-Trent was characterised by $\dot{n} > 0$ and $\dot{E}_0 < 0$, signalling a recovery of a district-like path of development in line with its historical ceramic specialisation. Instead, for Prato we find the combination $\dot{n} > 0$ and $\dot{E}_0 > 0$, suggesting that the spawning of new productive knowledge in the area tended to go together with a reduction of the traditional dominance of the textile specialisation. This could be a sign of a turn towards a more polycentric industrial asset. However, the volatility of *n* raises some doubts upon such interpretation, and points instead to the possibility of an impending fragmentation of the productive structure.

In the next two parts, we deepen the analysis to see what nuclei have grown, to attempt linking information about changes in the number of know-how nuclei and entropy -$\dot{n}$ and E_0 - and to shed light on the districts' trajectories of change. We will restrict the analysis to a comparison between the beginning and the end of the selected period (2005-2013) in the two IDs. A different type of statistical elaborations would concern the association of the analysis of the nuclei of productive know-how with indexes of performances of the IDs' firms, considering for example unemployment, turnover, profits, export and import. This has to be deferred to further research.

5.2. Qualitative analysis of the Stoke-on-Trent district

We start with Stoke-on-Trent and consider the diagram showing on the vertical axis the number of firms in each know-how nucleus and on the horizontal axis the list of nuclei identified by the cluster analysis of all sectors (Figure 4). The distribution of nuclei is captured by the histograms in solid line for 2005 and in dot line for 2013. The numbers at the top of the tall bars flag up the sectoral codes of the most populated nuclei.

Today, the traditional ceramic tableware sectors (Manufacture of ceramic household and ornamental articles - SIC 23.41; and Manufacture of other ceramic products -SIC 23.49) appear to be not much populated in our calculations, and can be found within the circle around nuclei 92 and 96 of the dot line (2013).

FIGURE 4

However, other nuclei are growing relatively fast. The dynamism of nuclei in manufacturing sectors with SMEs is signalled by the growth of "Other manufacturing" (SIC 32.99) with 106 units in 2005 and 147 in 2013. This sector seems to include ceramic artists, bespoke ceramic manufacturers, kiln manufactures, fireplace manufacturers and components makers related and unrelated to ceramic.

The presence and dynamism of the service sectors are also very important. As shown in Table 3, knowledge intensive services activities have emerged and are populated by SMEs new nuclei that could be related to the old manufacturing tradition, to an increasing strength of complementary manufacturing nuclei linked to the historical ceramic manufacturing, and to engineering sectors. We also find that a nucleus of SMEs related to urban services is growing too, like 'Other personal service activities n.e.c.' (SIC 96.09).

TABLE 3

This does not modify the overall image of an ID where we find an increasing multiplicity of know-how nuclei thanks to the activities complementary or unrelated to the historical

ceramic tableware specialisation (with $\dot{n}$ >0). Indeed, we find the emergence of new set of high tech service specialisations, which drives the upswing of the concentration ($\dot{E}_0 < 0$).

Those results, together with the stability of the large firms' nuclei and the increasing presence of SMEs' nuclei, seems to signal the vitality of the Marshallian industrial atmosphere in the contemporary Stoke-on-Trent district, in line with Tomlinson and Jackson (2013).

5.3. Qualitative analysis of the Prato district

In the case of the Prato district, the diagram is made more complicated by the fact that the dataset also contains information about the origin of the entrepreneur and size of the firm, each distinguished by three modalities. Three of the nine possible combinations are not present over the period.[13] In this ID there is a fundamental distinction between the traditional core of nuclei and the *other* nuclei. The district's traditional textile sector is represented by five nuclei with Italian entrepreneurs and small firms with a slightly growing firm number from 2005 to 2013.

The histogram on variations in the composition of know-how nuclei (see Figure 5 below) for Prato presents visible differences from the one on Stoke.

FIGURE 5

Table 4a includes the variation in the number of firms in the Prato core nuclei covering in particular Italian owned, small firms.

TABLE 4a

The textile core seems to be preserved, although with a shift from manufacturing to trade, also considering the well-known erosion of the Italian artisan micro-firms pool – unfortunately not covered by the current database. We also find four emerging nuclei of Italian small firms in the service sectors. Such growth appears to be weakly related to an

increase of knowledge intensive business services (see Table 4b), and signals more directly a reduction of the cognitive centrality of the textile core. We also observe a significant increase in the weight of nuclei of medium sized firms with Italian ownership; and the growing presence of nuclei of small firms with non-Italian ownership – further confirming a growing fragmentation of the core of multiplicity of the district.

TABLE 4b

5.4. A graphic representation

The conceptual framework on the multiplicity states of districts and the possible paths of change described in Table 1 and Table 2 has here been applied to Prato and Stoke, but its novelty is that it can used more generally to trace the evolution of districts and ascertain its ongoing trajectories.

FIGURE 6

In Figure 6, we trace the trajectories of change over time of Prato and Stoke-on-Trent over the 9 entries of Table 2. The starting point are about in the 1980-90 drawing on the historical sources referred in Section 4, while the end-points coincide with their current state (2005-2013) consistent with the above cluster analysis.

6. CONCLUSIONS

The paper is framed within the debate on the long-term evolution of local production systems, such as industrial districts (IDs), and on the impact of changes in the composition and dynamics of the localised knowledge and collective learning on their trajectories of change.

The unit of analysis is the district, not the sector (Becattini, 1989). We propose to explore ID development trajectories looking at the complex set of localised know-how as a whole. We are indeed concerned with understanding the interplay of the localised core industries with other related or unrelated industries that are present in the ID. They are all part of the multiplicity of the local system. These nuclei of know-how can be a crucial internal force of renewal for the core specialisation or offer opportunities of branching out from - or in alternative to - such core.

Developing further the concept of multiplicity as a local set of know-how nuclei, each one including firms showing a high degree of cognitive similarity, we have introduced two indexes ($\dot{n}$ and $\dot{E}_0$) to track the local paths of change from birth, development, maturity to decline/renewal.

One key finding is to extrapolate the conditions that signal lock-in and decline in IDs, as well as trace possible renewal. Indeed, in mature IDs, such as Stoke and Prato, we have been able to unearth changes in the number and the concentration of know-how nuclei that relates to such trajectories. Even if we have not entered the matter of policies of industrial development and renewal, the results of such analyses could also help in addressing direct or indirect interventions on the stock of embedded knowledge for adverting situations of lock-in or helping recovery and consolidation of positive paths.

This issue has increased in importance in regional studies of new methodologies and approaches to study the evolution of districts but also other forms of local production systems, under the assumption that the full extent of the economic activities of a *place* can be captured and their multiplicity fully portrayed. This work links with studies that look at the empirical and analytical relations between the multiplicity states, the evolution of the institutional structure, and the performances of the local firms in terms of innovation and competitiveness (Mistri, 2009). On a more general level, it would be necessary to go deeper

on the meaning of different types of multiplicity of nuclei of know-how as regards the cohesion or the fragmentation of the local cultural foundations (Becattini, 1989). All this is left to future research.

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[1] IDs' reproductive capabilities draw on the vitality of the local system of specialised SMEs and its interdependence with the community of people (see for examples Becattini, 2001; Dei Ottati, 1994a; Trigilia, 2001).

[2] Of course, the local dynamics is inserted in deeper circles of local reproduction of values and cultural orientations (Becattini, 2004, Trigilia, 2001), as well in larger circles of flows of knowledge and resources at

national and international levels (Becattini and Rullani, 2004; Morrison, 2008), sometimes bringing about difficult challenges to the adaptability capabilities of the district (Bellandi and Santini, 2017).

[3] In this sense, the ID's dominant mode of innovation is the 'DUI-mode' (Jensen et al., 2007).

[4] See Bellandi and Santini (2017) for a classification of ID paths of development and the related states of maturity.

[5] In particular, we apply the Gower (1971) dissimilarity coefficient, that can cope with data that are expressed in mixed scale (quantitative, interval, nominal or ordinal data, ratios, missing values). The dissimilarity index can be expressed as follows: $G_{ij} = \frac{\sum_{h=1}^{k} \delta_{ijh}\, s_{ijh}}{\sum_{h=1}^{k} \delta_{ijh}}$

where s_{ijh} measures the dissimilarity between firm i and j for variable h, and the weight δ_{ijh}=0 when there is a missing value. There are several clustering methods available for hierarchically clustering district actors. We tested with Ward's method, single linkage, and complete linkage, all producing the same result. We decided to adopt the Calinski and Harabasz (1974) index in this model. It is computed as [trace B/(n - 1)]/[trace W/(k - n)] where k is the total number of items and n is the number of clusters in the solution; the maximum hierarchy level indicates the correct number of partitions in the data.

[6] We refer to Bellandi and Santini (2017) for maturity (state 5), impending decline (state 6) and prolonged maturity (state 8) states and on the relation between such states and those considered in the literature on cluster life-cycles (Menzel and Fornahl, 2010).

[7] For example, Aynsley - 1775, Minton - 1793, Wedgwood – 1759, and Spode - 1780, were important sources of international reputation for the district.

[8] The Act impinged on pollution problems produced by the traditional technologies of bottle kilns. Huge investments were needed to substitute the bottle kilns and vertical integration allowed a relatively cheap solution to such problems.

[9] In 2005 the Royal Doulton was bought by the Waterford Wedgwood, summing-up to a 70% of the market share (Sacchetti and Tomlinson, 2009).

[10] As suggested by Tomlinson and Branston (2014), the official data does not capture employment related to sub-contracting activities of the ceramics industry.

[11] See Tomlinson and Branston, 2014; Hervas-Oliver et al., 2011; Sacchetti and Tomlinson, 2009.

[12] It is maintained here that a general proxy of the geographical delimitation of a compact centre of industry and life is given by functional economic area, that is, for example, travel-to-work-areas in the UK (De Propris, 2009) and local labour market areas (LLMA) in Italy (Sforzi, 2009). They correspond to the sets of municipalities

recalled above and identified by the relative national statistical offices on the basis of data collected at the beginning of the 2000s.

[13] In the figure the sequence of the six relevant combinations, each including a certain number of nuclei (clusters) ordered by sectoral code, is defined by a qualitative criterion of relative importance within the district: Italian entrepreneur - small firms; Italian entrepreneur – medium sized firms; Chinese entrepreneur - small firms; Other kinds of ethnic entrepreneur- small firms; Italian entrepreneur - large firms; Other kinds of ethnic entrepreneur- medium sized firms.

Figures and Tables

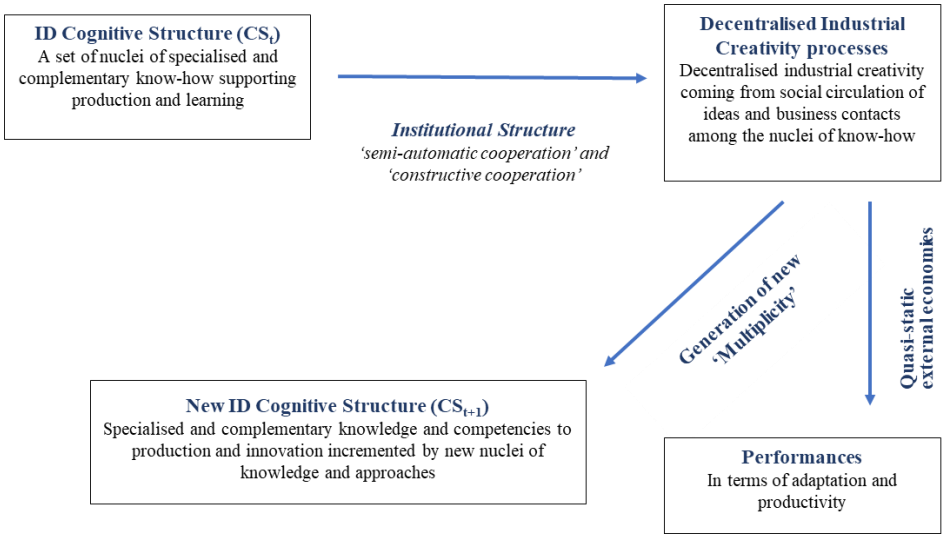

FIGURE 1

Multiplicity and creative processes within an Industrial District

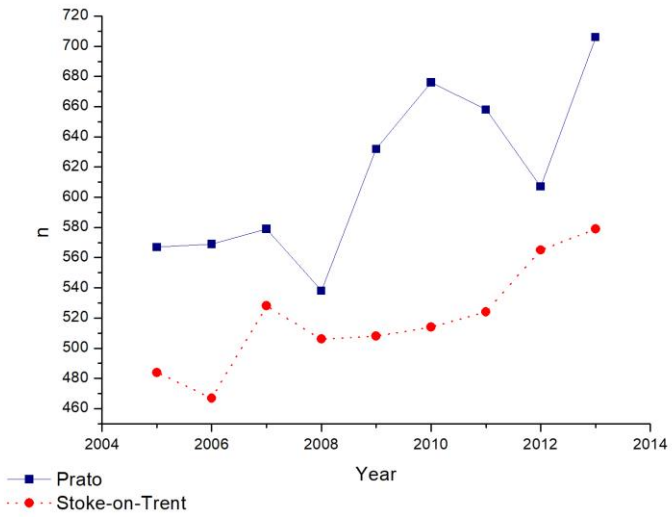

FIGURE 2

Trend in the number of know-how nuclei into the Stoke-on-Trent and Prato districts (2005- 2013).

Source: Author's elaboration based on AIDA and FAME datasets

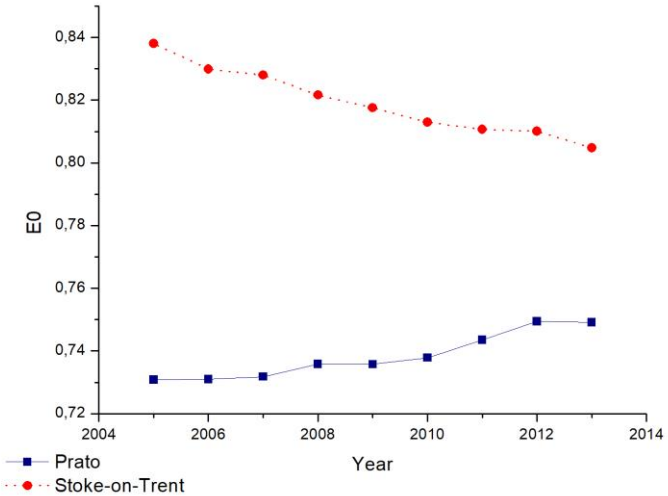

FIGURE 3

The Normalized Entropy Index of the Stoke-on-Trent and Prato districts (2005- 2013).

Source: Author's elaboration based on AIDA and FAME datasets

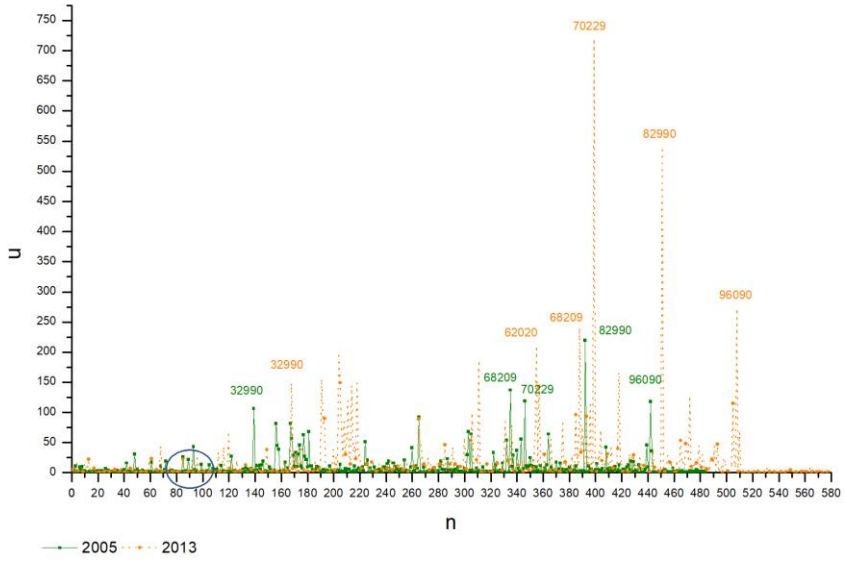

FIGURE 4

Reconfiguration of know-how nuclei into the ceramic district of Stoke-on-Trent. Comparison between 2005 (solid line) and 2013 (dotted line).

Sources: Author's elaboration based on FAME dataset

Legend: 32.99 'Other manufactoring n.e.c'; 62.20 'Computer consultancy activities'; 68.20/9 'Letting and operating of own or leased real estate (other than Housing Association real estate and conference and exhibition services) n.e.c.'; 70.22/9 'Management consultancy activities (other than financial management)'; 82.99 'Other business support service activities n.e.c'; 96.09 'Other personal service activities n.e.c'.

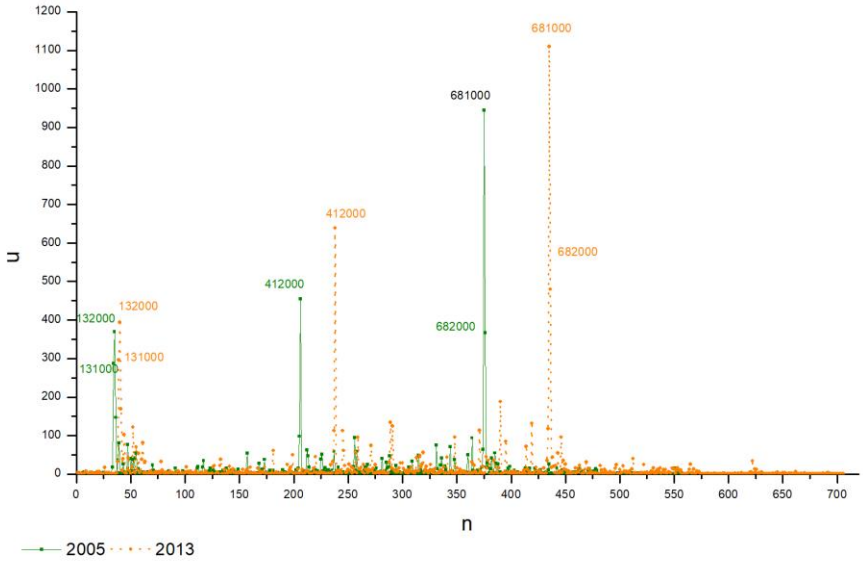

FIGURE 5

Reconfiguration of know-how nuclei into the ceramic district of Prato. Comparison between 2005 (solid line) and 2013 (dotted line).

Source: Author's elaboration based on AIDA dataset

Legend: 13.10.00 'Preparing and spinning of textile fibre'; 13.20.00 'Weaving of textile'; 41.20.00 'Construction of residential and non-residential buildings'; 68.10.00 'Buying and selling of own real estate'; 68.20.00 'Renting and operating of own or leased real estate'.

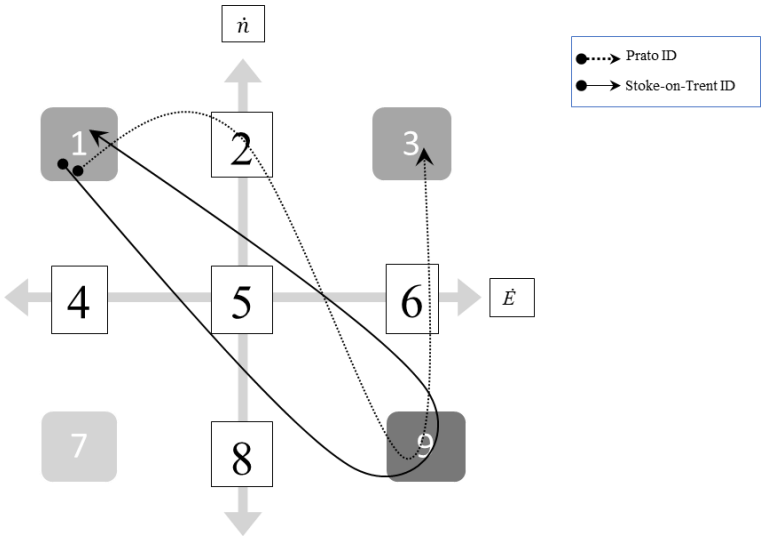

FIGURE 6

Paths of change across multiplicity states

	$\dot{E}_0 < 0$	$\dot{E}_0 = 0$	$\dot{E}_0 > 0$
$\dot{n} > 0$	1. Both the number of know-how nuclei & relative concentration are increasing	2. Number of know-how nuclei increase & relative concentration is stable	3. Number of know-how nuclei increases & relative concentration is shrinking
$\dot{n} = 0$	4. Number of know-how nuclei is stable & relative concentration is increasing	5. Both number of know-how nuclei & relative concentration are stable	6. Number of know-how nuclei is stable & relative concentration is shrinking
$\dot{n} < 0$	7. Number of know-how nuclei is shrinking & relative concentration is increasing	8. Number of know-how nuclei is shrinking & relative concentration is stable	9. Both number of know-how nuclei & relative concentration are shrinking

Table 1. Multiplicity Variation Index and Entropy Variation Index

	$\dot{E}_0 < 0$	$\dot{E}_0 = 0$	$\dot{E}_0 > 0$
$\dot{n} > 0$	1. Increasing specialisation and stronger polycentric bases. Robust expansion after birth or strong renewal phase	2. Path of organic development (Quasi-Steady state)	3. Polycentric development with risk of fragmentation. Renewal or structural change
$\dot{n} = 0$	4. Increasing mono-centric specialisation. Birth phase	5. Maturity phase (Steady State)	6. Fragmentation and preservation of multiplicity. Impending decline of the core
$\dot{n} < 0$	7. Increasing specialisation upon an impoverished multiplicity. Rationalization and risks of lock-in	8. Cognitive descaling led by the effects of prolonged maturity	9. Fragmentation and impoverished multiplicity. Lock-in in face of crisis and decline of the district

Table 2. ID multiplicity states and paths of development

Nuclei	No of firms from 2005 to 2013
'Management consultancy activities (other than financial management)' (SIC 70.22/9)	from 119 to 717
'Other business support service activities' (SIC 82.99)	from 219 to 536
'Computer consultancy activities' (SIC 62.02)	from 68 to 207
'Other professional scientific and technical activities (not including environmental consultancy or quantity surveying)' (SIC 74.90/9)	from 64 to 165

Table 3. Service nuclei in Stoke-on-Trent

Nuclei	No of firms from 2005 to 2013
'Preparation and spinning of textile fibres' (ATECO 13.10)	from 287 to 296
'Weaving of textiles' (ATECO 13.20)	from 370 to 394
'Finishing of textiles' (ATECO 13.30)	from 147 to 169
'Manufacture of machinery for textile/apparel/leather production' (ATECO 28.94.1)	from 54 to 61
'Wholesale trade of textiles' (ATECO 46.41)	from 95 to 134
'Wholesale trade of clothing and footwear' (ATECO 46.42)	from 59 to 125

Table 4a. Manufacturing nuclei in Prato

Nuclei	No of firms from 2005 to 2013
'Construction of residential and non-residential buildings' (ATECO 41.20)	from 455 to 639
'Restaurants and mobile food service activities' (ATECO 56.10)	from 71 to 189
'Data processing, hosting and related activities; web portals' (ATECO 63.11)	from 94 to 131
'Buying and selling of own real estate' (ATECO 68.10)	from 945 to 1110

Table 4b. Service nuclei in Prato