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Mapping paradigm shifts in the geography of innovation

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Abstract. The study quantifies important theoretical tendencies in the geography of innovation in a historical view based on a novel big-data approach. It shows that the field was "born" only in the nineteen eighties after long periods (i.e. the first half of the 20th century) of analysing economic growth and regional development without endogenising the production process of innovation. The paper presents important shifts in the basic assumptions of models with the increasing use of the terms "economic instability" or "asymmetric information" instead of "economic equilibrium" and "perfect information". These mean a deviation from traditional neoclassical regional economics, which is reflected in the fact that "geography of innovation" gained the same level of popularity in the 2000s as "industrial geography". The paper shows that although the decline of the Marshallian term "industrial district" stopped in parallel with the work of Becattini, a new innovation systems theory took over the relative frequency of mention of the industrial district by the turn of the new millennium.

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1. Introduction

"Innovation" is both an old and new term because of its rapid transformation in the 20th century from having a negative religious meaning towards a positive economic connotation. The emergence of the term "innovation" in the scientific economic literature has been fast – covering half century, as we present it in the following sections – but the sophistication of models used in regional sciences often lagged behind actual economic challenges. As the big-data-based text analysis presented in this paper demonstrates, statistically speaking, the scientific field (or subdiscipline) of the geography of innovation was "born" in the eighties. Although the relative frequency of the usage of the term "innovation" in English scientific literature saw a more than five-fold increase between 1950 and 2008, policymakers have not been provided with a comprehensive quantified examination of the theoretical dynamics of the field, which is the objective of this paper.

Until the 21st century, large-scale, digitised datasets concerning the scientific body of literature were not available. There is not only a need, but also an opportunity to quantify the dominant paradigms of the 20th and 21st centuries. Our method based on a big-data approach is a novel and viable way to gain more insight into the inherent shifts in scientific trends – compared to the traditional analyses of scientific literature building on more subjective factors. This may be a great support to economic policy so that it can find the most frequently used theoretical frameworks and grasp the dynamics between them in order to identify the barriers to innovation. As a result, policy may gain the potential to strengthen regional comparative and competitive advantages as a basis of regional economic resilience.

The objective of the paper is to map the central, main models of the geography of innovation in the 20th century and to mark the two theoretical endpoints of this period. This would allow us to make a comparison between the main approaches of the beginning and the end of the century. The paper is intended to highlight the shifts in relative frequencies of mentions of regional-industrial economics on the one hand and the geography of innovation on the other (and the related terms). Our hypothesis states that there is a change-point after the millennium where the geography of innovation gains the same level of popularity as regional-industrial approaches.

2. Data and methods

The research is based on secondary sources and, in addition to a qualitative literature review, it also builds on a database created by Google researchers in 2011. This database contributed to the emergence of a new scientific approach called *culturomics* – the analysis of cultural trends based on big-data analysis of large bodies of texts. After digitising 12 percent of the world's published print books, Michel et al. (2011) selected the five million copies digitised – with the help of optical character recognition (OCR) technology – in the highest quality in terms of the ease of search. Most of the books come from forty different university libraries around the world accounting for five percent of books ever written globally (Michel et al., 2011). The continuously increasing corpus of the database contains around 500 billion words, of which around 72%, approximately 361 billion, are English (Michel et al., 2011) (1).

The limitations of the database – as is the case in many big-data applications – are as follows: it does not allow for data cleaning, volumes cannot be separated by genre, it does not include periodic publications, including journals, and occurrences of more than five consecutive words cannot be searched for. At the same time, the database brought scientific methodological advances and made it possible to analyse changes in human thinking on a larger database than ever before. In this study, we make statements about the history of theories and concepts based on relative frequencies (word usage relative to the corpus of all words in a given year) derived from this database with the help of

search algorithms. We present trends with a three-step "smoothing factor", meaning an average over a three-year period, to make the charts easier to read (2). The data is presented in a case-insensitive way, and includes plural forms when applicable. The methodology allows us to achieve a seemingly paradoxical result: to tell (and map) the story of the geography of innovation based on quantifiable data. We believe this methodology will enhance previous methods by adding quantitative trend analysis to the discipline of history of thought.

3. Endogenising innovation

In this section we not only present the intellectual roots of the geography of innovation, beginning with Marshallian thoughts on local industrial districts, but also the path to the current mainstream framework, marked by innovation system models. In general, the discussions in the framework of regional economics were limited to the results and consequences of innovation in the first half of the 20th century. The production process of innovation remained largely an external factor to the models of regional economics in this period. The eEmergence of the geography of innovation from the eighties started to change this theoretical *status quo* (Fig. 1–3).

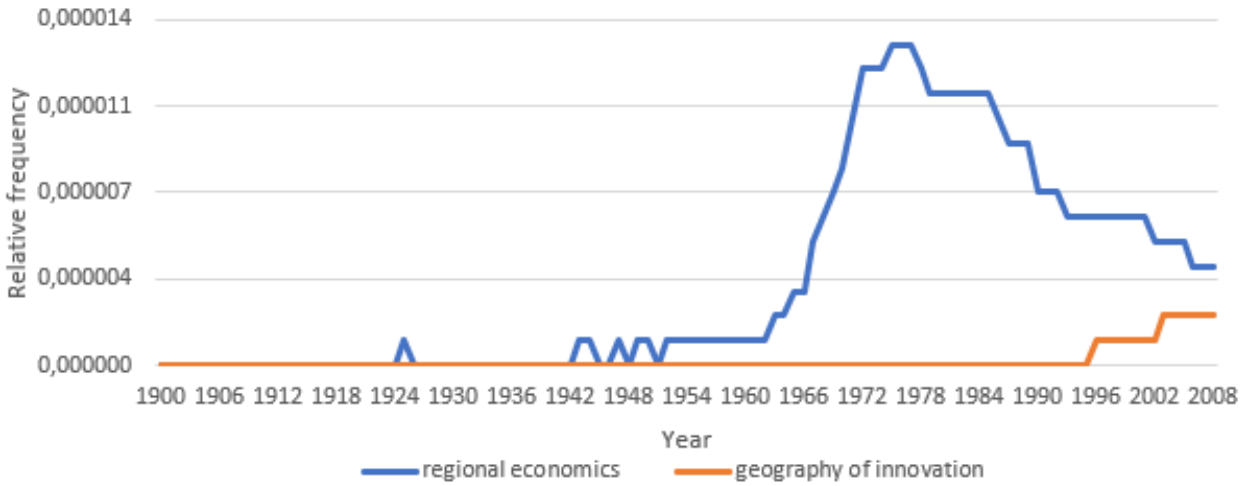

Fig. 1. Relative frequencies of "regional economics" and "geography of innovation"
Source: Ngram

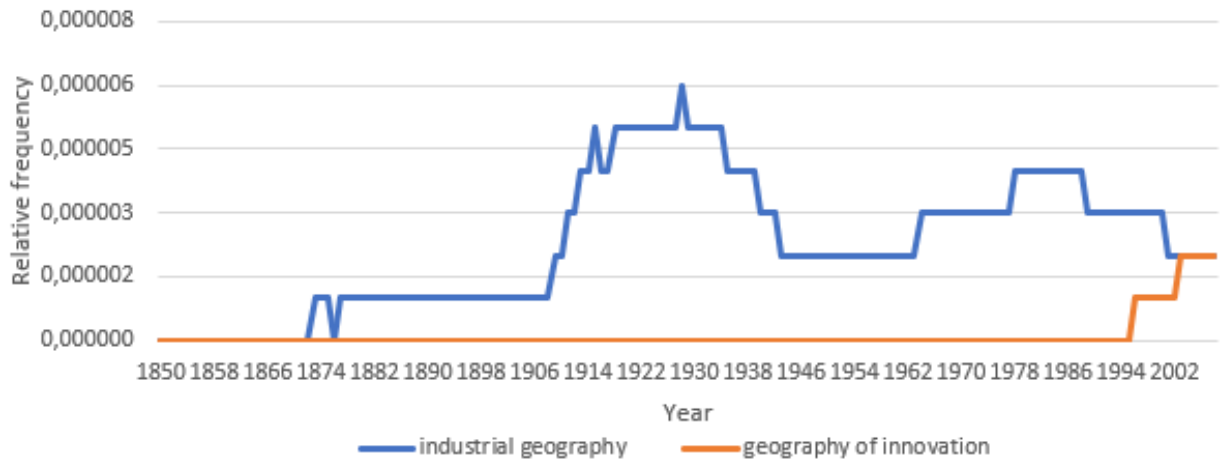

Fig. 2. Relative frequencies of "industrial geography" and "geography of innovation"
Source: Ngram

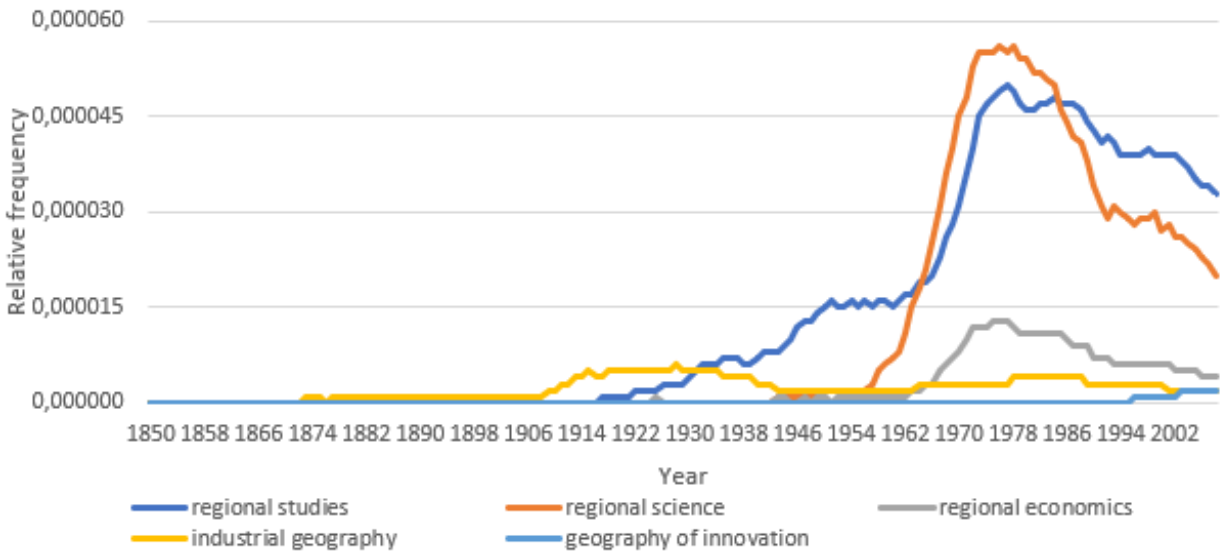

Fig. 3. Relative frequencies of terms referring to regional disciplines
Note: data includes plural forms where applicable.
Source: Ngram

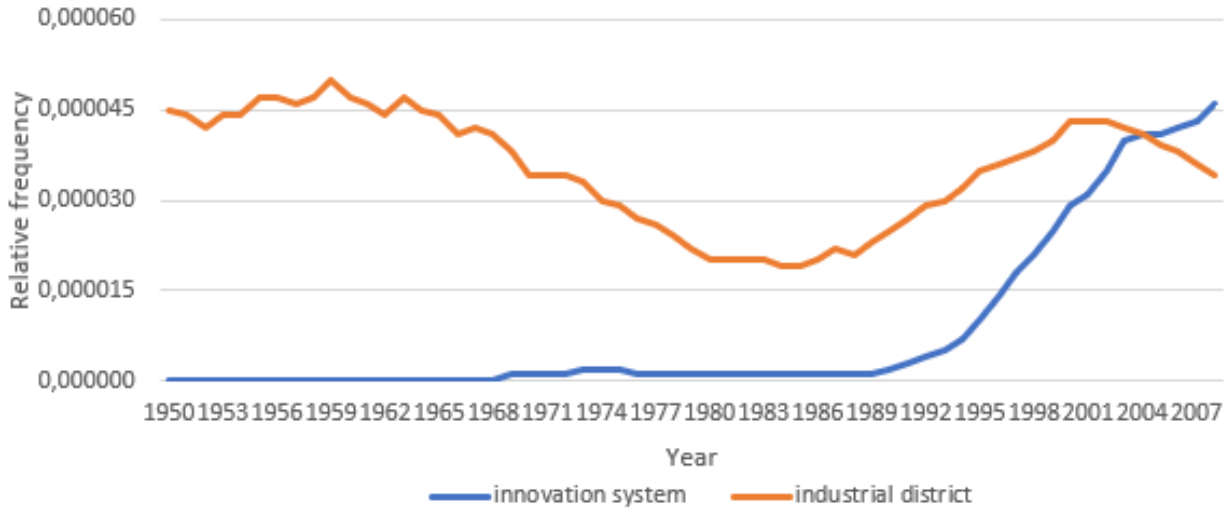

Fig. 4. Relative frequencies of "innovation system" and "industrial district"
Note: data also includes plural forms.
Source: Ngram

The industrial district theory of Alfred Marshall was intended to provide insight into the local concentration of small and medium sized enterprises (SMEs) with the analysis of the so-called industrial atmosphere, technological complementarities, agglomeration and localisation advantages, but primarily the external economies of scale (Bekele-Jackson, 2006). Marshallian theories are sometimes considered to be the original roots of later literature studying the role of territory and space in firm interaction and innovation development (Ferretti, Parmentola, 2015) so it may not have been a coincidence that – as the fourth figure presents – Marshallian theories were reinvented in later decades (Becattini, 1990; Saxenian, 1991; Scott, 1993) and have gone through several generations (Sforzi-Boix, 2015; Schiavone, 2004; Bellandi-Propris, 2015). Our analysis can confirm the revival of the industrial districts school on data.

There is no clear consensus about the distinctive, defining features of different theories in innovation geography. As a result, there are debates about whether models "exclude" or "include" each other. According to Ferretti and Parmentola (2015),

national innovation systems (Lundvall 2011) are the "descendants" of Marshall's industrial districts, also integrating the learning region, innovative milieu, the triple helix model and business clusters (Ferretti, Parmentola, 2015). In this case the theoretical history of the 20th century can be interpreted as one broad model framework that is becoming more sophisticated over time. Cooke (2009), on the other hand, argues that Moulaert and Sekia (2003) equate milieu and industrial district approaches, although considerable differences may arise between models. He adds that while industrial district schools often refer to innovation systems, "*the latter school never cites the former, though the reverse may have occasionally applied*" (Cooke, 2009: 303). *"It is argued that the territorial dynamics creates specific interdependences among the actors and between the actors and the institutions that evolve into a peculiar industrial and technological trajectory. Several analytical frameworks share this approach, in particular the industrial district paradigm, the innovative milieu conceptual model, the learning region concept and the regional innovation systems approach*" – writes Santos and Simoes (2014: 39) emphasising similarities, arguing that these terms may indeed be considered to belong to the same wider approach. There are examples of taking the middle position, such as Porter and Ketels (2009) arguing that the spatial concentration of industrial corporations in an industrial district is an early form of a cluster, but it is not cluster in general.

As for the endogenous explanation of the creation of innovation, the industrial district approach has its deficiencies. According to the theory, localised industries could develop and transform into industrial districts, where there is a distinctive role of local resources, creating unbreakable links between companies and the local economic spatial environment. Although the theory focused also on the role of *atmosphere or external effects on agglomeration* (the school is also called "classical agglomeration theory" (Bekele-Jackson, 2006) and became a precedent of a related school analysing localisation and urbanisation economies), these theoretical experiments were not adequate to endogenise the creation of innovation, which remained effectively a phenomena external to the model. The new economic geography of Paul Krugman (1991) in the nineties built on this Marshallian strain, and pointed out that the spatial location of economic activities is a result of the opposing phenomena of agglomerating (*centripetal*) and dispersionary (*centrifugal*) forces (Bekele-Jackson, 2006). Although the useful modelling notions of *monopolistic competition* and *increasing returns* were introduced by the new economic geography school, the causes of innovation remained largely unexplained.

The focus point of Schumpeterian ideas lay not on the causes of innovation in geographical terms either. Schumpeter was primarily interested in analysing the result of innovation – which is creative destruction – where a lesser role was given to space and geography and the causes of innovation. From this perspective, Schumpeter did not create a theory of the emergence of innovation in a geographical sense (Ruttan, 2001). The early relationship with geography was that Schumpeter made a distinction between invention, innovation and the spatial diffusion of innovation (Greenacre et al., 2012; Simmie, 2005). Schumpeter also inspired the S-curve shaped diffusion model (Stenzel, 2007; Lissoni, 1995).

Later, the location theories of Weber, Hoover, Lösch and Christaller had a generally neoclassical framework implying the imagination of space as a featureless plain where companies can freely choose their location, optimising in space, often without transaction costs or without considering the socio-economic characteristics of places (Weber, 1929; Hoover, 1948; Lösch, 1954). Space is distance and distance equals to cost in this framework, that is why these theories added another production factor to the production function, which was the cost of spatial location. These theories examined how space and location are used and distributed by different economic actors and despite economic growth and its diffusion often being analysed by them, their concept of space has a limited social-institutional aspect and context through which a deeper understanding of the causes of innovation would be possible.

The growth pole theories of Perroux (1955) – building on the cumulative causation theory of Myrdal (1957) – argued that growth happens in space and has an intensity. As partly an application of earlier location theories, the central place with the most intense economic activity is the growth pole,

which is also the origin of the diffusion of growth and innovation in the economic space (Szajnowska-Wysocka, 2009). The argument was often made – sometimes implicitly – that policy is able to and should create growth poles to foster innovation by focusing a huge amount of concentrated public and private investments in certain locations, regardless of the fact that innovation in the model is mainly the end result of the working of poles and is not the locating and creating factor of economic concentration. Although, as Fig. 7 proves, the original growth pole concept "decreased" in terms of relative frequency of mention by the turn of the new millennium, the insight has been still further applied and can be discovered behind the analysis of cities, industrial and science parks, special economic zones or university centres even today (Gavrila-Paven, 2017; Meyer-Hecht, 1996).

On the other hand, the theories of a new approach – which we can refer to as "relational geography" because of its focus on complex relationships instead of the mere analysis of economic actors – succeeded at least partly in describing innovation production in their models. The *flexible specialisation* school (Piore-Sabel, 1984) called for an analysis of industry agglomeration that embeds economic space in the social and the cultural spheres. This was a reaction to the economic crisis of the 1970s (Bekele-Jackson, 2006). This school analysed the rise of subcontracting processes to more flexible, smaller, specialised firms, creating smaller clustered groups of firms instead of the earlier large, integrated factories. These new forms of industrial district theories started to open the innovation "black box", emphasising social and cultural networks, face-to-face relationships and the difference between tacit and explicit knowledge (Bekele-Jackson, 2006).

These latter notions were the contributing factors of the so-called industrial milieu – a theory having its origins in Marshallian industrial atmosphere, revived and rediscovered by Becattini (1991b) for Italian industrial regions (Bellandi-Propris, 2015). In fact, Marshall did not use the term "milieu", which was invented by Becattini (1991a) (Belussi-Caldari, 2009). The main motivation was the "*success of many Made In Italy products related to the growth of agglomerations of small firms*" where "*increasing returns are realised thanks to a local division of labour among small and medium sized firms embedded in a delimited territory*" (Bellandi-Propris, 2015: 76). Since this period marked an era in which studies began to argue that the new period of capitalism has knowledge and learning as its most important resource and activity, the theory focused on local knowledge creation, information sharing and spillovers in a common localised learning

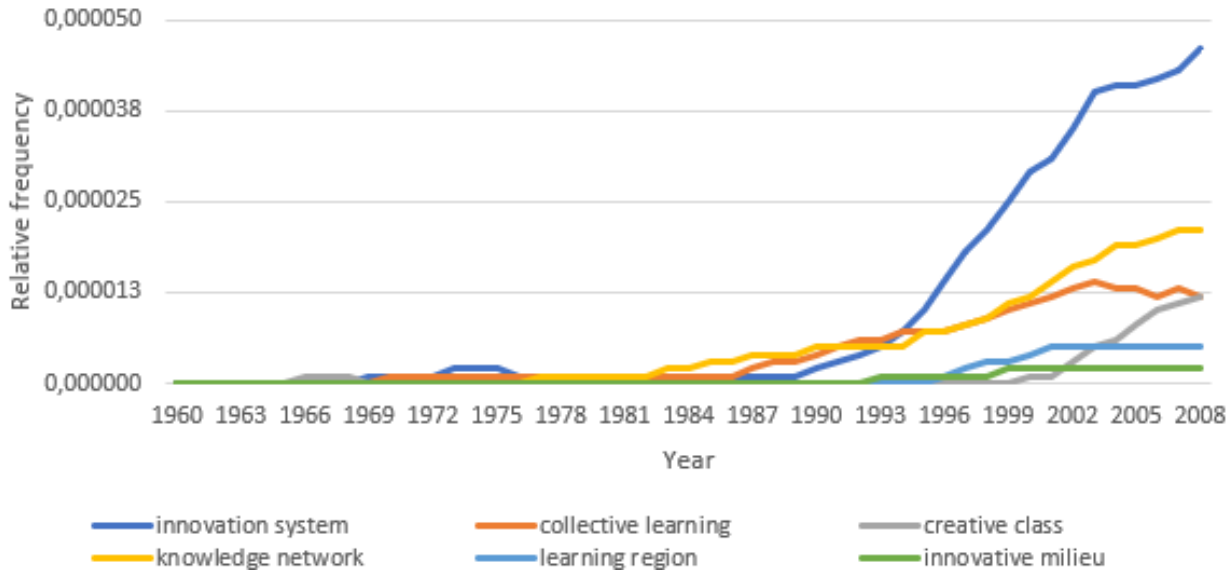

Fig. 5. Relative frequencies of terms related to location theories
Note: data includes plural forms where applicable.
Source: Ngram

process (Bekele-Jackson, 2006). This was a step towards endogenising innovation production. As suggested by Fig. 8, this new added meaning could revive the Marshallian industrial district approach in a transformed form.

In the last decade of the century, economic geographers, spatial planners and regional scientists embraced the *learning region* (Hassink, 1999). Similarly to the *innovative milieu* – it is argued that milieu does not explain how innovation is created in a company that is not part of the milieu (Hausman, 1996) – the *learning region* also had the problem of vague definitions, the lack of solid empirical basis and the problematic differentiation from earlier, existing notions. At the same time, it helped to reinforce the new paradigm in economic geography in a broad sense, since it built on the knowledge creation of networks, pointing also to the problem of the evolutionary phenomena, path dependency and path exhaustion (Frenken, 2017). The concept gave way to the distinction of different local industrial paths. For instance, a local industrial development path may be progressive, producing more innovation if there is a high level of *related variety* in the inner structure of the local economy. Building on *related variety* may promise the successful establishment of new, local industrial development paths, based on locally embedded institutions and knowledge bases (Boschma, 2017). Without presenting all schools of thoughts in detail, we add that the learning region approach became integrated into the evolutionary and innovation system schools in its many elements – both of which analyse economic change caused by the learning actors embedded in a given institutional context (Fig. 5).

4. Results

Our empirical text analysis shows two opposing trends when *regional economics* and the *geography of innovation* are concerned (Fig. 1). The relative frequency of the term "*regional economics*" saw a strong, five-fold increase in less than a decade, while the steep declining path already started in the beginning of the seventies (Fig. 1). The term "geography of innovation" did not exist in the literature for a long time – its relative frequency was not comparable to that of regional economics until the eighties. Up to 2008, the field gained strong visibility. If we define traditional regional economics as a school of models where innovation is an external process – because, for example, we accept the definition that a central focus of regional economics is related to spatial general equilibrium – then we can make a distinction with the geography

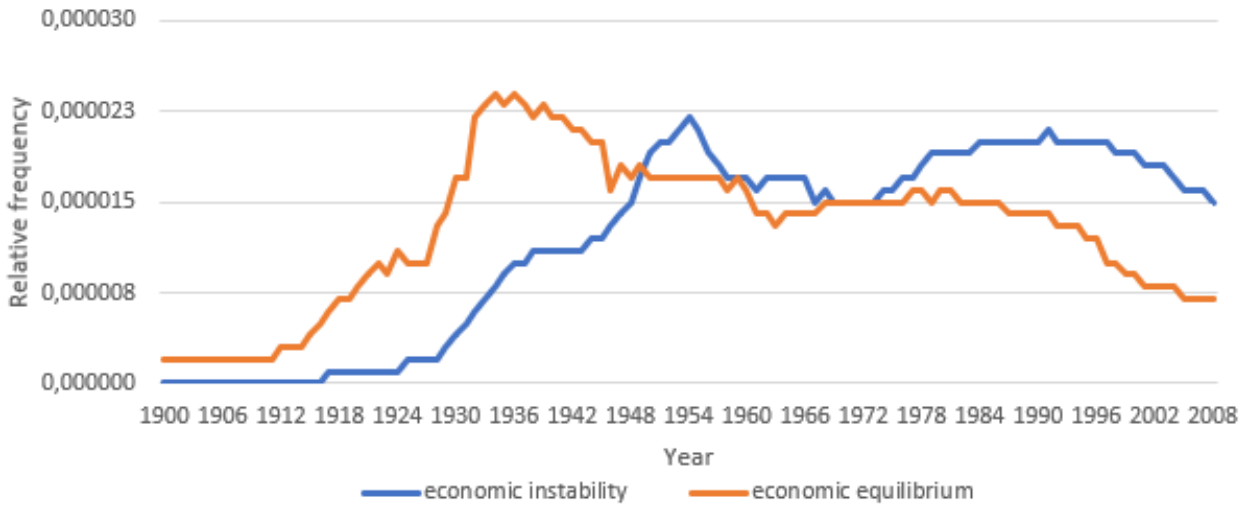

Fig. 6. Relative frequencies of "economic equilibrium" and "economic instability"
Note: data includes plural forms where applicable.
Source: Ngram

of innovation, which aims to describe the innovation process endogenously, with more focus on instability. Instability is a phenomenon itself deviating from the general equilibrium-modelling that may be initiated by revolutionary innovations.

In this sense, the second half of the 20th century seems to be a period of paradigm shift from the neoclassical spatial equilibrium theories to frameworks giving way to instability. An important field embracing the instability concept is evolutionary economics. Analysing the terms "economic equilibrium" and "economic instability" yields that until the first half of the 20th century, the former was more often used, while the latter gained prominence in the second half (Fig. 6). The 2000s also marked a turning point in the relationship between two fields: *industrial geography* analysing industrial activities and primarily location

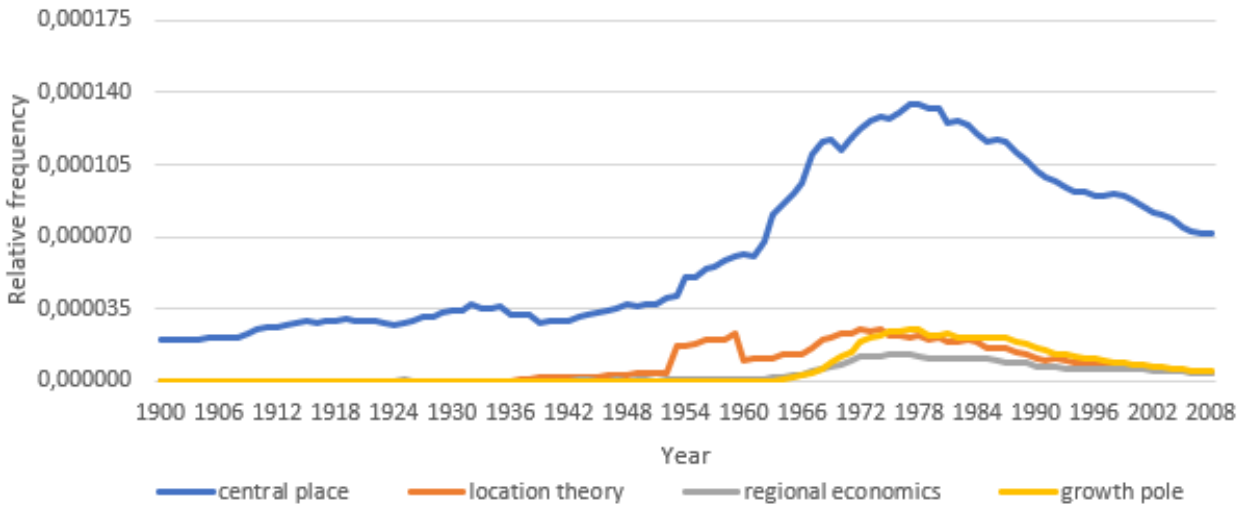

Fig. 7. Relative frequencies of terms related to location theories
Note: the data includes plural forms where applicable.
Source: Ngram

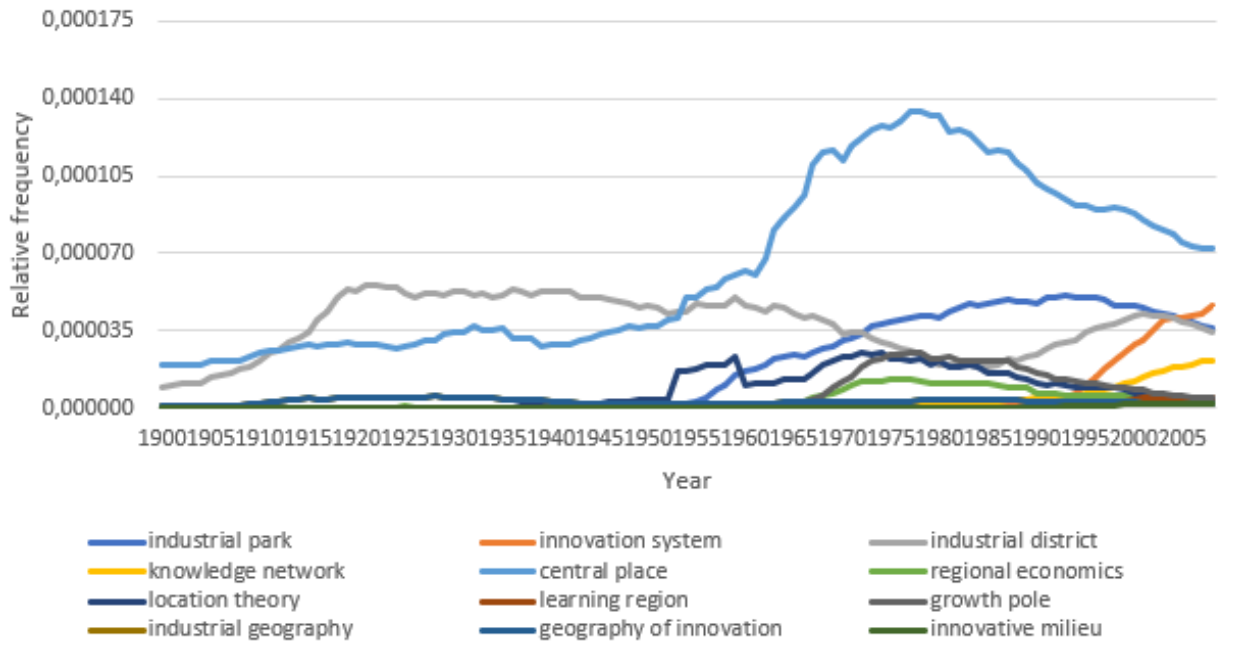

Fig. 8. Relative frequencies of terms related to the main paradigms of innovation geography
Note: data includes plural forms where applicable.
Source: Ngram

choices versus the *geography of innovation* analysing knowledge producing activities and choices related to learning (Fig. 2).

5. Interpretation of results

To understand and quantify the main historical modelling shifts we need to examine the basic elements of different models. These key terms of different approaches are analysed in Figures 7 to 10 to provide insight into the changes in scientific word usage – and hence the conceptual frameworks. The first half of the century was dominated by the terms "industrial district" and "industrial geography", showing the increased focus on industries, sometimes at the expense of innovation theories. In the middle of the century, *location theories* became the new mainstream – which were renewed, spatial equilibrium-seeking, neoclassical descendants of industrial district approaches. Figure 7, based on our big-data text analysis, indicates that the term "central places" had a higher relative frequency than any other examined phrase in the sixties and seventies. It was more than a historical coincidence that the terms "central places", "regional economics", "location theory" and "growth pole" showed remarkably similar dynamics. In this case we observe a unique example, where many phrases belonging to the same wider approach exhibit a similar trend, drawing a visual "map" of the rise and fall (?) of a paradigm.

When it comes to the next mainstream integrating theory, it is more challenging to identify one – in this case only the phase of emergence can be noticed, but a decline has not started. We do not argue that only one or two "schools" dominate the field, since it is open to debate how to define a school, but we think that there are many common ideas and assumptions that create strong links between newer theories. The nineties and the 2000s saw completely new phenomena: the emergence of i*nnovation systems, knowledge networks, learning regions* and *innovative milieus*. *Collective learning* and the creative class are also symbolic representatives of the new approaches. We argue that based on their shared focus on information and knowledge, these approaches could be called "systemic approaches" to innovation.

Figure 8 presents the summary of approaches. A noteworthy finding is that while industrial parks dominated the literature and innovation systems were non-existent around the nineties, 18 years later the two have almost the same frequency of use. It can be argued that the phrases used by the scientific community point to the fact that researchers started to speak a new language beginning in the nineties. This change in word usage patterns analysed by our method can be seen in our figures. We think that the geography of innovation can be an accurate field to integrate these new ideas.

6. A qualitative development path of the geography of innovation

We quantified an important paradigm shift – the increasing popularity of the geography of innovation. Another finding is that industrial geography – and the theoretical tools and schools behind this term – had a long historical "cycle" that was interfered with by the geography of innovation (Fig. 2). The analysis proves that the two frameworks reached the same level in terms of relative frequency of mention by the year of 2008, since the scientific community was paying more attention to the geography of innovation than before. The two are not exclusive, but imply an analytical choice – to understand industrial phenomena through the lens of innovation, instead of analysing innovation as a subfield or consequence of industrial geographies. Many regional scientists may have also started to use terms that we attribute to the geography of innovation. This is a sign that there is indeed a tendency in the literature to endogenise the creation of innovations, which is also reflected in the main theoretical transition in the 20th century from the school of *industrial district* to the "rising star" of *innovation systems* – the latter being the most dominant school of thought in terms of relative frequencies in the 2000s (Fig. 4).

The comparison of the industrial district and innovation system models is needed to understand the change in human thinking about technological-

economic innovation (Fig. 4). According to Muscio (2006), the two models are related but analyse different aspects of development. The author also argues that a *regional innovation system* can support several *industrial districts*. This implies that the innovation system is a broader term, examining the relationship between a wide array of actors and districts, not only the links and interactions between small local companies. The main assumption of innovation systems is that external and internal linkages and networks between actors matter to innovation, which is produced also by conscious networking besides learning by doing, using or interacting (Reig-Otero et al., 2014). Bellandi-Propris (2015) describes three versions or stages of industrial district models arguing that *"each generation of industrial districts have emerged and grown in correspondence with specific technological, institutional and market conditions"*.

Cooke (2009) call the innovation system model the "master narrative" because it contains the principles of many other approaches. In line with this argument, we could title our study as the way to "the master narrative" in spatial innovation research. Cooke (2009) thinks that the *industrial district, technology cluster* and *regional innovation system* theories are all founded on the concept of networking. In this sense the sophistication of models changed through time in the first century of the geography of innovation. Innovation system models are interested in *"features of industrial districts, such as collaboration, trust, small-firm networking, local productive systems and social capital"* so the interest of the two model families is also similar. The system models have an interest *"in variety, search, selection, routines, trust, embeddedness, collaboration, innovation, learning, path dependence, institutional change, disequilibrium and knowledge intermediation practices of institutions and organisations, including firms"* (Cooke, 2009).

Lazzeretti et. al (2008) build an innovation system model that is based on the industrial district: they develop a taxonomy of three regional systems of innovation. The first is the *"territorially-embedded regional innovation system"*, which is based on the industrial district, territorially-rooted tacit knowledge and local atmosphere. In the second model – *"regionally-networked innovation system"* – public support and supporting infrastructures have a prominent role. Their third model is the *"regionalised national innovation system"*, in which decisive innovation activities happen outside the region, and the region is a centre connected to the national or international innovation system (Lazzeretti et al., 2008). An empirical result of ours is the corroboration of this triad: in fact, as Fig. 9 presents, the industrial district, location theory and innovation system terms (and "waves") could be matched in their essential content with, respectively, the *territorially-embedded regional innovation*

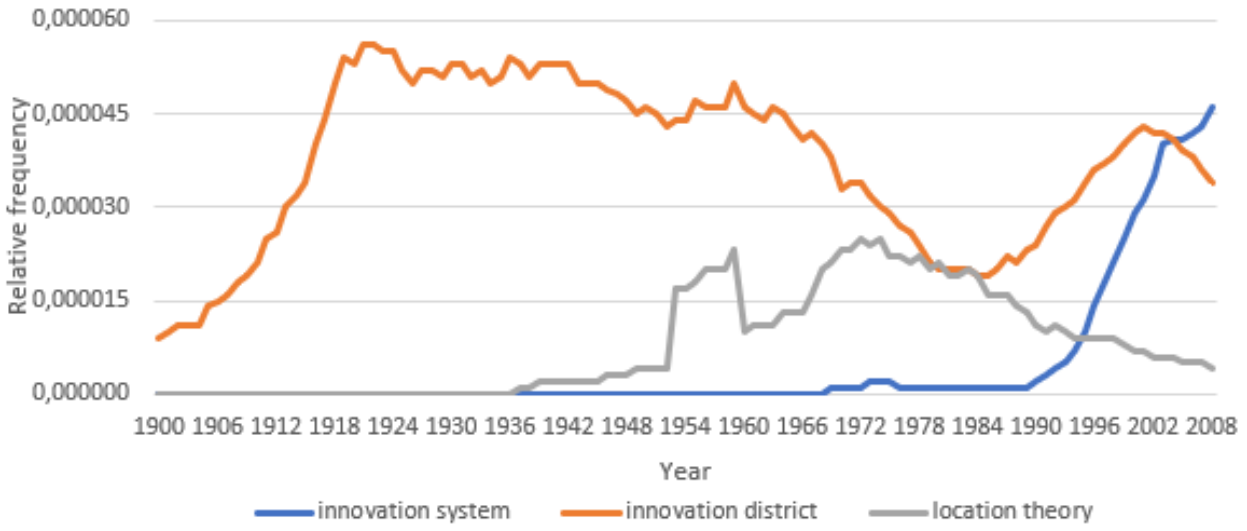

Fig. 9. Three paradigms of innovation geography and the decline of location theory
Note: data includes plural forms where applicable.
Source: Ngram

Table 1. Industrial district, innovative milieu/learning region and regional innovation system – a comparison

	Industrial District	**Innovative Milieu/Learning Region**	**Regional Innovation System**
Emergence	Spontaneous; as local productive system.	Spontaneous/Induced; as cognitive entity.	Induced; as organisational entity.
Predominant culture	Industrial atmosphere	Entrepreneurial culture	Scientific and entrepreneurial culture.
Productive system	Industrial; productive specialisation; specialisation in line with a sectoral division of labour; SMEs; vertically disintegrated.	Industrial and tertiary; diversification of production; large and SMEs; quasi-vertical integration; open.	Industrial and tertiary; diversification of production; large and SMEs; quasi-vertical integration; open.
Reticular structures	Compacts; networks without a strategic centre.	Compacts; networks with leader or pivot enterprises.	Networks with pivot enterprises or institutions.
Dominant forms of learning	By doing, by using, by interacting.	By doing, by interacting, by networking.	By searching, by networking.
Dominant modalities of innovation	Incremental; adaptative; of the product and of the process.	Incremental and radical – first of its kind; emphasis on organisational innovations.	Incremental and radical – first of its kind; emphasis on organisational innovations.
Growth dynamics	Competition-emulation cooperation; based on an enlarged social mobilisation; socially supported entrepreneurial risk.	Competition-cooperation; induced by the activation of information and knowledge flows; entrepreneurial risk institutionally supported.	Cross-fertilisation; highly induced by the institutional universe; dynamic adjustment between the entrepreneurial and institutional spheres.
Potential risks	Socio-technological lock-in; barriers to the entrance of new players; growth of hierarchisation phenomena.	Technological and relational lock-in; exit barriers.	Technological and relational lock-in; exit barriers: institutional sclerosis.

Source: Santos (2009)

system, the *regionally-networked innovation system* and the *regionalised national innovation system*.

The main theoretical differences between industrial districts and innovation systems are the following (Table 1). The former is seen as a local productive system producing goods from learning by doing, using and interacting, while the latter is a broader organisational entity, producing knowledge from searching and networking. Although Alfred Marshall himself was interested in knowledge and the entrepreneurial atmosphere, industrial district models provide less insight into the creation of innovations. Current understanding of the emergence of innovation in these districts at a meso- and micro-level is "relatively poor" (Reig-Otero, 2014 refers to Iammarino, 2005; Malerba and Vonortas, 2009; Cantner et al., 2010). Cooke (2009) also writes that district models themselves *"had little or nothing to say about innovation"*.

Industrial district models have industrial cultures embedded, while innovation system models have scientific-entrepreneurial cultures embedded. In the latter entities, there are central companies and institutions, while districts usually exist without strategic centres. As a result of their characteristics, industrial districts create incremental, adaptive innovations, while more radical innovations arise from innovation systems. The latter could be viewed as a broader model, integrating industrial districts and many other approaches – including evolutionary or institutional schools.

The differences between the two schools represent a theoretical development process not only in time but also in sophistication between the two endpoints of the first century of the geography of innovation. *"Although the barren debate over the conceptual differences between clusters, IDs and RIS the definition of LRIS (industrial district, regional innovation system and local regional innovation system – ed.) covers all these theoretical constructs in the sense that all are founded on the idea of networking"* (Reig-Otero, 2014). This identical basis does not imply a lack of essential differences: *"research on ID and clusters is moving from a predominantly static approach to more dynamic analysis to understand how spatial concentrations and networks emerge and evolve along time"* (Reig-Otero, 2014). O'Connor et al. (2018) argue that the industrial district emphasises the *"local division of labor of an industry and the interaction between a community of people and a population of firms within a socio-territorial entity"*. They think that the cluster approach focuses on geographic concentrations of several actors: *"interconnected companies, specialized*

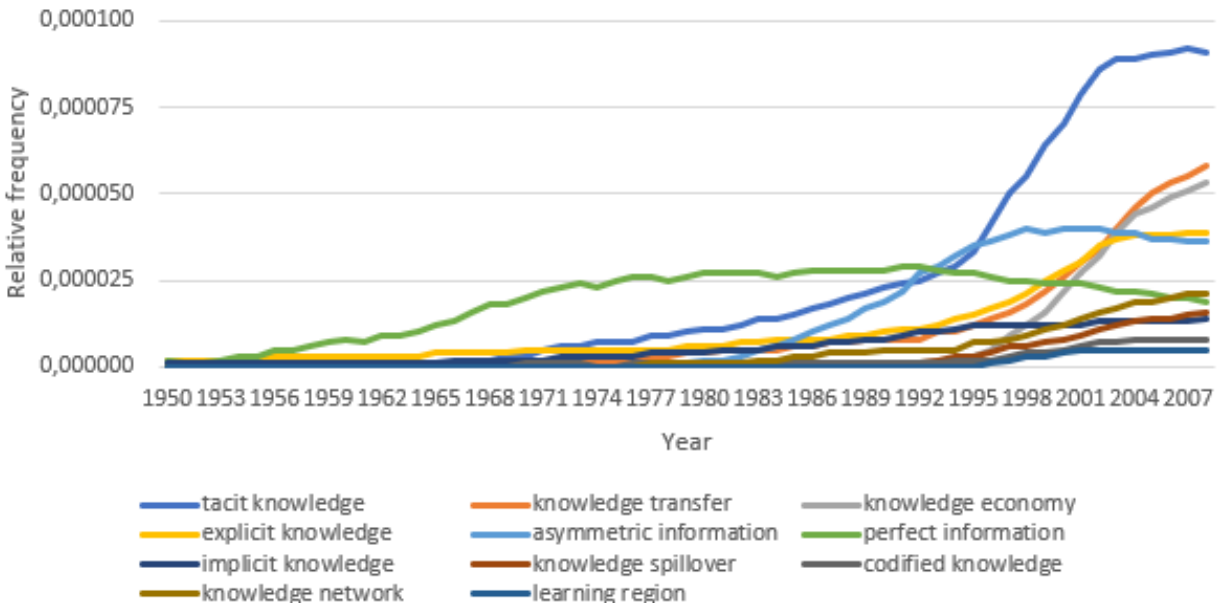

Fig. 10. From perfect to asymmetric information
Note: data includes plural forms where applicable.
Source: Ngram

suppliers, service providers, firms in related industries and associated institutions that compete but also cooperate" (O'Connor et al., 2018). They describe innovation systems as networks and institutions linking knowledge-producing hubs – universities and research labs – and firms in a region. These are the linkages that allow the spillover or transfer of imperfect knowledge between organisations making the regional economy more innovative and competitive. Another important difference is the lack of research institutions in classical district models, which is often neglected by authors using the term for the Silicon-valley (Ferretti-Parmentola, 2015). Ferretti and Parmentola (2015) determine two criteria on which the use of "industrial district" as a term could be justified: (1) *"the presence of a community of firms localized in the same area"* and (2) the *"industrial atmosphere"*.

We argue that one main change embracing the first century of innovation geography is that the analysis of the life cycle of information became more sophisticated. The unique "atmosphere" in the industrial district described by Marshall did not leave a role for these information and knowledge factors. In fact, our data shows that the hegemonic attributive of the word "information" in the second half of the 20th century was the notion of "perfect", an assumption of neoclassical regional economics (Fig. 10). It may be surprising for many that the quantifiable endpoint of the theoretical "hegemony" of this assumption came only in the middle of the nineties when – in 1994 – the popularity of *asymmetric information* overtook the old neoclassical assumption, marking the beginning of a new era in which a more pluralistic approach emerged about information and knowledge. "Tacit" and "explicit" knowledge, "the knowledge economy", "knowledge transfer" and "asymmetric information" are all terms that – statistically speaking – were barely used up until the nineties but took over the *perfect information* paradigm from then on. These trends explain themselves – theories of the millennium were created in an era in which information was no longer considered to be perfect, costless, frictionless and featureless, but imperfect, asymmetric, costly to acquire and different in types (see the literature on knowledge bases).

An innovation system model builds on knowledge bases and has actors that produce and distribute information through common learning activities, helped by supporting infrastructure and institutions. The term "knowledge spillover" has been used only since the nineties in the literature and shows the importance of networks, common learning and the local spread of tacit information. Knowledge spillover is an antithesis of perfect information – there would be no need for the transfer of knowledge if information was perfect. In this sense, economic geography and its subfield, the geography of innovation are a theoretical response to the strict assumptions of neoclassical frameworks that made the key challenges of the current, new global era difficult to analyse.

7. Conclusion

We argue that at least three large theoretical waves can be discovered with the help of search algorithms on big data. The first is the period of the original industrial districts in the first part of the 20th century, focusing on the narrowest local spatial concentration points. The scope became broader in space (but still focused on local concentrations) with the new wave of *central places, location theories* and *growth poles*. This period can be called the era of applied location theories, building on the industrial district concept. The beginning of the third large wave started around the nineties and it can be identified from the increased usage of phrases describing knowledge and information and the fast appearance of *innovation systems*. These three large waves show the constant broadening of the scientific focus in space first from (1) a district to (2) a growth pole containing potentially many industrial districts, then to (3) a system that embeds many regional growth poles. In this sense, we could corroborate the triadic taxonomy of regional systems of innovation by Lazzeretti et al. (2008). Although the focus has been broadened in space, it also became deeper in terms of analysing new issues, such as the underlying institutional, informational mechanisms behind local industrial processes.

8. Notes

1. Publicly available: https://books.google.com/ngrams. As the authors present: "we restricted our study to the question of how often a given '1-gram' or 'n-gram' was used over time. A 1-gram is a string of characters uninterrupted by a space; this includes words ('banana', 'SCUBA') but also numbers ('3.14159') and typos ('excesss'). An n-gram is sequence of 1-grams, such as the phrases 'stock market' (a 2-gram) and 'the United States of America' (a 5-gram). We restricted n to 5 and limited our study to ngrams occurring at least 40 times in the corpus. Usage frequency is computed by dividing the number of instances of the n-gram in a given year by the total number of words in the corpus in that year. For instance, in 1861, the 1-gram 'slavery' appeared in the corpus 21,460 times, on 11,687 pages of 1,208 books. The corpus contains 386,434,758 words from 1861; thus, the frequency is 5.5×10^{-5}" (Michel et al., 2011).
2. So a smoothing factor of 3 gives the average of the values (in this case relative frequencies for individual years) over a three-year period. We can call it a rolling or running average.

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