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Decline or renewal? Factors influencing the evolution of mature industrial clusters

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Abstract:

The evolution of industrial clusters has received much attention in the recent literature on evolutionary economic geography (EEG) and regional science. However, scientific results on the influence of different factors on the decline or renewal of mature industrial clusters are scarce. Therefore, this study identifies different factors: preconditions, triggering events and self-augmenting processes, and examines their influence on declining or renewing industrial clusters. In order to obtain transferable results, this meta-analysis is based on 69 individual empirical case studies from different countries and industries. The empirical results show, firstly, that the decline and renewal of industrial clusters is driven by different preconditions, triggering events and self-augmenting processes. Secondly, these factors change over time and may have both positive and negative dimensions. Finally, the decline of industrial clusters is more often associated with unfavorable preconditions and triggering events, while self- augmenting processes are more often found in the context of cluster renewal.

Keywords: Cluster, Evolution, Decline, Renewal, Meta-analysis

JEL Classifications: O33, R10, R11

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1 Introduction

The concept of industrial clusters has become widespread in scientific literature, mainly covering the function of clusters and positive effects leading to clustering whereas development aspects, such as failure and decline, have been disregarded (Hassink, 2016; Østergaard & Park, 2015). Or as Isaksen (2018, p. 242) summarizes in a simplified way: "Clusters are […] associated with an aura of success" During the last decade the aspects of failure and decline as well as renewal and a change of fields of industrial clusters (Hassink, 2016; Lorenzen, 2005; Staber, 2010) have increasingly attracted the attention of the scientific debate. Such negative externalities can cause agglomeration economies to suffer from their high degree of specialization and a lack of technological heterogeneity (Cho & Hassink, 2009; Grabher, 1993; Hassink, 2005; Martin & Sunley, 2006; Menzel & Fornahl, 2010; Schmidt, et al., 2020b).

It is commonly observed that structural conditions of regions, such as resources, as well as trends, disruptive technological changes or expanding regulation can cause industry-specific challenges, possibly leading to cluster decline as geographically industrial agglomerations do not inherit strong adaptation capacities per se (Saxenian, 1994). Industrial concentrated agglomerations, according to Hassink (2010, p. 451) can turn into "insular, inward-looking systems" since the evolution of clusters is "not a one-way street" (Wrobel, 2015, p. 273). On the one hand, industrial clusters appear to be more exposed towards exogenous shocks due to the industry specific focus and a resulting, often one-sided orientation of the regional economy. On the other side, due to existing network structures, established inter-firm linkages and lead-firms local industrial clusters can be more adaptable to change. Both, positive and negative developments such as decline or renewal can result from this, as several case studies show.

Clusters are often defined as geographic concentrations of interconnected firms and institutions of a certain field, including actors all along the value chain (Porter 1998, 2000). In this study, Porter's cluster concept is used, which is based on the so-called Porter Diamond – firm strategy, structure and rivalry; factor conditions; demand conditions; and related and supporting industries are the main factors. Despite an expansion of theoretical perspectives, such as knowledge-based (Bahlmann & Huysman, 2008; Bathelt, 2008) and multidimensional cluster approaches (Bathelt, 2004), key aspects of the definition such as the importance of geographical proximity, institutional ties, sectoral concentration and social factors remain upheld (Frankowska, 2020). Resulting characteristics attributed to clusters are sectoral and/or geographical concentration; division of labor and cooperation between entities within the region; specialization of firms and/or the labor force (Sellitto & Luchese, 2018) by building on a shared institutional setting – based on social factors and trust (Frankowska, 2020; Götz & Jankowska, 2017; Sarturi et al., 2016) – as well as knowledge exchange (Terstriep & Lüthje, 2018).

This study investigates decline and renewal of mature industrial clusters. Therefore, the analysis focuses on factors favoring the decline or renewal of local industrial clusters and their relevance to cluster evolution. The underlying categorization of influencing factors as precondition, events and processes has been developed by Brenner (2004) and already tested in a meta-study on the emergence of clusters by Brenner and Mühlig (2013). Since the identification of relevant factors in the decline or renewal of a local industrial cluster is an empirical question, a descriptive meta-analysis was conducted, in order to obtain transferable results. This analysis integrates empirical results of 69 individual case studies, which address cluster decline, renewal or both.

In general, we aim to contribute to the literature on the evolution of mature industrial clusters, focusing on decline and renewal, in different ways. Firstly, it provides empirical results based on a large number of case studies and thereby summarizes their results on cluster evolution. This includes results based on different yet related theoretical concepts of industrial agglomerations such as industrial districts and clusters. Secondly, it combines insights on decline and renewal of industrial clusters, which is rather scarce in the existing literature. A larger number of publications either focused on aspects of cluster decline or processes of renewal. Lastly, this study complements the theoretical discussion on mature industrial clusters. The theoretical literature, some of which already identifies factors for cluster evolution, is used as a basis and complemented by additionally identified factors of this study.

The analysis shows that both the decline and the renewal of an industrial cluster are driven by specific preconditions, triggering events and self-augmenting processes, which differ at different stages of development. These factors can be present in both positive and negative dimensions and can change over time. Declining industrial clusters are more likely to be associated with the influence of unfavorable preconditions and triggering events, while several self-augmenting processes are more likely to be found in the context of cluster renewal.

The study is structured as follows. After this general introduction, the theoretical aspects are outlined and the relevant factors of the analyzes are discussed in section 2. This is followed by a presentation of the methodological aspects, such as data collection and methodology, in section 3. On this basis, section 4 presents the results in terms of cluster decline, renewal or both. Finally, section 5 summarizes the central aspects and suggests directions for further research, while discussing potential policy implications and options for future research.

2 Theoretical Background

The literature offers different approaches to frame the development of local industrial clusters. On the one hand, dominant approaches focus on the evolution of clusters; on the other hand, cluster development is framed by the life cycle hypothesis, with a special emphasis on cluster emergence. In

order to set the stage for the empirical analysis of the factors influencing the evolution of mature clusters, the following section takes a closer look at the phenomenon of cluster evolution in general, the stages of development of mature clusters – decline, renewal or both – and the factors relevant to decline or renewal that can be derived: preconditions, triggering events and self-augmenting processes.

2.1 Evolution of industrial clusters

The most recent literature focusses on long-term cluster evolution and negative influences challenging successful cluster transformation (Schmidt et al., 2020b). Therefore, the maturity of studies is building on the cluster life cycle approaches which are referring to different stages of evolution – emergence, development/growth, maturity, decline and renewal (Martin & Sunley, 2011; Menzel & Fornahl, 2010; Wal & Boschma, 2011). Unlike other cluster approaches before, they are less focusses on cluster success and growth and stronger consider negative developments and the related driving factors behind the evolution (Martin & Sunley, 2006; Schmidt et al., 2020b). Furthermore, this literature links key evolutionary cluster approaches such as path dependence (including path creation, renewal and plasticity), lock-ins and resilience (Crespo et al., 2014; Hassink, 2016; Hervas-Oliver & Albors-Garrigos, 2014; Martin, 2012; Menzel & Fornahl, 2010; Simmie & Martin, 2010).

This study is based on the cluster life cycle approach by Menzel and Fornahl (2010), which is not a representation of the local industry life cycle (Østergaard & Park, 2015). This approach assumes four development stages – emergence, growth, sustainment and decline (Menzel & Fornahl, 2010). Even though the approach is wide spread, it is criticized for its deterministic and simplifying notion of complex and cyclic processes. Therefore, Martin and Sunley (2011) suggest a modified adaptive cycle model. This framework identifies multiple cluster development factors based on reciprocal interactions between a cluster and its external environment: exploitation, reorganization, conservation and release (Martin & Sunley, 2011). Additionally, there are further, less popular models addressing both, cluster and industrial district development (Baumgartinger-Seiringer et al., 2021; Zucchella, 2006).

2.2 Mature industrial clusters – decline or renewal

As industrial clusters reach a certain stage of maturity or consolidation, they are prone to negative developments. Economic advantages based on cluster dynamics are not permanent (Hassink, 2016) and economic agglomerations can turn into insular, inward-looking systems (2010, p. 451). A loss of competitiveness and decline may result from this (Grabher, 1993).

Decline of industrial clusters

Such declining industrial clusters can be characterized by a decreasing number of firms due to shake-outs and a lack of new firm creation, a resulting decrease in the number of employees, and a loss of its diversity (Menzel & Fornahl, 2010; Østergaard & Park, 2015; Schmidt et al., 2020b). Initial strengths – such as high degree of specialization, close interfirm linkages, and political support – can hinder innovation (Grabher, 1993). The co-location of firms and the shared labor pool increases competition for (highly) skilled workers, wages are rising, and labor poaching intensives (König, 2023). Due to the geographical proximity, job hopping within a cluster is easier for employees, which leads to firms losing valuable knowledge to nearby competitors. Furthermore, local knowledge spillovers and loss of information could weaken additionally firms' performances and strengthen competitors (Østergaard & Park, 2015).

Besides sudden external changes in the industry, technological and market changes as well as a strong dependence on trajectories, especially lock-in effects are discussed to explain the decline of clusters (Grabher, 1993; Isaksen, 2018; Østergaard & Park, 2015; Schmidt et al., 2020b). The concept of lock-ins has been linked to regional development of industries (Grabher, 1993) and connected to the evolution of industrial districts and clusters (Hassink, 2007, 2010, 2016). Lock-ins can occur whenever the initial strengths of specialized regional economic agglomerations become barriers to innovation (Grabher, 1993; Hassink, 2010; Isaksen, 2018). The following forms are commonly distinguished: Firstly, a functional lock-in referring to problematic inter-firm relations, secondly a cognitive lock-in based on a closed and narrow-minded common world- view or mindset, and lastly, a political lock-in due to institutional settings obstructing industrial change (Hassink, 2010). These three forms can be described as regional lock-ins (Boschma, 2005; Hassink, 2010; Martin & Sunley, 2006). While cognitive and political lock-ins are used in this analysis, the functional lock-in is not used as individual factor due to further specifications: e.g. buyer-supplier-relations, innovation activities or internal and external knowledge transfer. This change of positive cluster dynamics into weaknesses is also discussed in the context of network approaches: embedded districts and cluster become over-embedded (Grabher, 1993; Granovetter, 1985) and dis-embedded as a result to decline and a following lack of competitive enhancement in embedded ties (Zucchella, 2006).

But decline is not necessarily driving an industrial cluster to failure and disappearance. Several contributions show that declining clusters can re-orientate their activities by integrating new technologies, initiate path renewal and thereby stabilize or enter a new growth phase (Desmarchelier & Zhang, 2018; Martin & Sunley, 2011; Menzel & Fornahl, 2010; Tappi, 2005).

Renewal of industrial clusters

According to Østergaard and Park (2015), there are several mechanisms of reorganization for clusters: the cluster can transform itself by shifting to a new field of activity (Menzel & Fornahl, 2010); renew itself and its' activities to start new growth phase and sustain its prosperity – e.g. focusing on innovation and diversification – (Chapman et al., 2004; Hassink, 2007; Trippl & Otto, 2009); maker minor adjustments – e.g. focus on cost reduction and imitation – leading to stagnation and gradual decline (Chapman et al., 2004; Hassink, 2007); or be replaced by a new cluster with a new identity and function, often in the high-tech segment (Martin & Sunley, 2011; Trippl & Otto, 2009).

Related to the renewal of old industrial systems and industrial clusters is the concept of regional resilience, which has recently emerged in the literature on regional development (Crespo et al., 2014). Despite its growing popularity, there is much ambiguity regarding the precise definition of economic resilience, an appropriate way to measure it, and the connotations of the term itself (Martin, 2012). In general, resilience can be described as the ability of a local or regional socio-economic system to recover from a shock (Simmie & Martin, 2010). The role of clusters in regional economic resilience is also discussed, as clusters do not automatically strengthen the resilience of regional development to economic downturns (Campi & Duenas, 2022). Both, declining and renewing clusters share determinants of resilience, such as industrial structure, human capital, policy and support structures, and geographic location (Kim et al., 2022).

Moreover, cluster renewal is linked to multinational cooperations (MNCs). MNCs increasingly locate their knowledge-intensive activities in clusters, which influences the existing local innovative activities (Østergaard & Park, 2015). Several positive spillover effects can be identified: an increase in foreign direct investment, knowledge acquired through the related global pipelines, which benefits both the MNCs themselves and the co-located firms through spillover effects, and an increasing heterogeneity of knowledge (Bathelt et al., 2004; Menzel & Fornahl, 2010; Østergaard & Park, 2015; Propris & Driffield, 2006). In general, cluster renewal can be supported by a well-developed regional innovation system and strong institutions of knowledge generation (Tödtling & Trippl, 2004).

Overall, renewal processes allow mature or declining industrial clusters to enter new life cycle phases and stabilize or grow again (Hassink, 2016), thus avoiding decline and eventual failure.

Factors of mature industrial cluster evolution

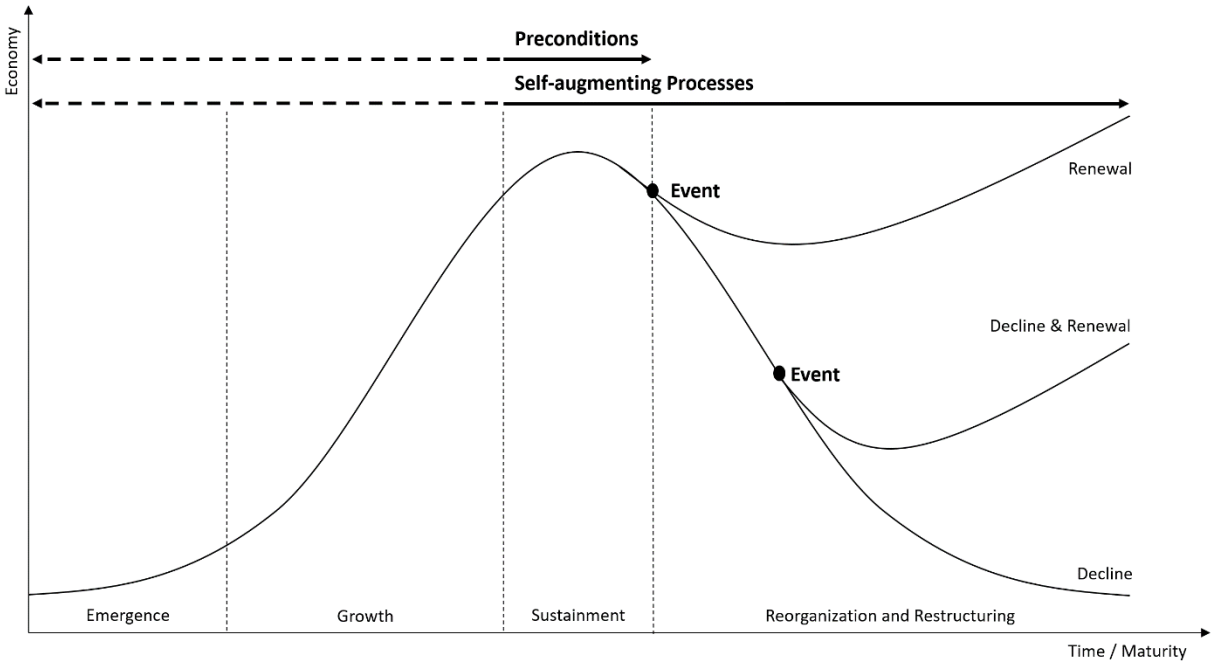
Although the existing scientific literature on the development of mature industrial clusters or districts focused on decline or renewal does not include publications that theorise and analyse such factors in a fundamental and comprehensive way, there are several studies that present factors and drivers of this development from specific perspectives. Most publications are based on the cluster concept, while only a few focus on (old) industrial districts or combine both concepts. On the one hand, evolutionary

perspectives, including life cycle approaches, that address adaptation and change, are common (Carli & Morrison, 2018; Harris, 2021; Hu & Hassink, 2018; Lorenzen, 2005; Mossig & Schieber, 2016; Schmidt et al., 2020a). On the other hand, there are also more specific approaches focusing on decline (Hoffmann et al., 2017; Isaksen, 2018; Zucchella, 2006) or renewal (Tödtling & Trippl, 2010; Trippl & Otto, 2009). In the following section, we take up these factors, grouping them into three areas and selectively adding others.

2.3 Differentiation of factors – Preconditions, events and processes

The following section builds on the theoretical aspects outlined above. The identified factors are classified as preconditions, triggering events and self-augmenting processes and are based on the concepts discussed previously and, in particular, on the literature on factors influencing the evolution of mature industrial clusters. To this end, the three areas of the factors are related to each other and to the different development stages throughout the evolution of clusters (see Figure 1). Although this study focuses on the evolution of mature industrial clusters, the underlying preconditions and self-augmenting processes were already present before each cluster reached its stage of sustainment. Therefore, during the life cycle of a cluster, preconditions and factors may arise at different times during the life cycle of a cluster. The triggering events are located prior to the following three developments: renewal, decline and following renewal, or decline of clusters.

Figure 1 – Stages of cluster evolution



Source: *Authors' own illustration, based on Menzel & Fornahl (2010, p. 218) and Martin & Sunley (2011, p. 1307)*

Preconditions: In general, technological and economic developments in regions are based on previous developments and established regional factors (Brenner & Fornahl, 2007; Brenner & Mühlig, 2013;

Tappi, 2005). The preconditions considered are local factors and resources present in an industrial cluster or industrial district. The following factors are characterized as preconditions: *Labor supply, universities and research institutes, firm structure, cooperative environment, competitive environment, cognitive lock-in, political lock-in, local capital market, hard location factors,* and *soft location factors* (see Table 1).

Triggering events: Local conditions do not determine the decline or renewal of a local industrial cluster alone, and the importance of triggering events at different stages of cluster development is widely recognized. Shocks and specific triggering events are described as further influences on regional economic development (Tappi, 2005). Among others, the concept of path dependencies, originally introduced by David (1997), frames technological and economic developments as well as events as dependent on previously initiated development paths (Brenner & Fornahl, 2007; Brenner & Jeddeloh, 2023; Tappi, 2005). According to Østergaard and Park (2015), economic recessions, natural disasters, and market and technological disruptions challenge the adaptive capacity of the cluster and are often associated with cluster decline. Therefore, seven triggering events are included: *Industry restructuring, external market changes, regulation changes, disruptive innovations, historical events, re-location of lead firms,* and *re-structuring of lead firms* (see Table 2).

Self-augmenting processes: In addition to the preconditions, the slightly different approach of self-augmenting processes is used for the following reasons: First, unlike preconditions, the factors listed below are dynamic processes that can be self- augmenting. Second, a local precondition may cause a process that is related but different (e.g. a competitive environment (precondition) may be described by different aspects than competitive interaction (process)). Third, both preconditions and processes can occur simultaneously. This is why we distinguish between preconditions and self-augmenting processes. The following factors are characterized as self-augmenting processes: *Training of employees, further education of employees, external recruiting of employees, buyer-Supplier relations, diversification, specialization, outsourcing, mergers and acquisitions, foreign direct investment, formation of firms, cooperative and competitive interaction, innovative activities, internal and external knowledge transfer, interaction with policy stakeholders, educational institutions, cultural institutions, and in (social) networks, gentrification,* and *reputation* (see Table 3).

In general, such factors are likely to change over time due to their embeddedness in local, regional and global social and economic processes; it can be assumed that the very same factors can be attributed to decline and renewal (Hassink, 2016; Martin & Sunley, 2006).[1] Multiple factors are framed both as conditional settings (preconditions) and as dynamic self-augmenting processes. Such particular factors

[1] The resulting issues and how to deal with them are discussed in the methods and data section.

may occur decoupled from each other. For example, a competitive environment as a precondition within an agglomeration addresses different aspects than the competitive interaction between local actors as a self-augmenting process.

In order to provide a comparable structure across the preconditions, triggering events and self-augmenting processes, all factors are presented in tabular form (see Tables 1 to 3). In addition, a thematic sequence of the factors within the three areas is used: Labor supply; Education and skills; Research and innovation; Firm characteristics and interactions between firms; Industrial and policy conditions; and Local conditions.[2] The following tables present firstly each individual factor, secondly a description with examples, thirdly the underlying basic theoretical concepts[3], and lastly the key contributions[4] for each factor included. These key contributions represent factors on the evolution of mature industrial clusters or districts and have been briefly introduced earlier (see end of section 2.2).

[2] This structure is not applied to the listed triggering events.

[3] A small number of factors are not clearly based on an underlying theoretical concept. These factors have been derived from the respective theoretical concepts. These factors are labelled "derived" in the following tables

[4] A small number of factors are not discussed in any of these key contributions. These factors are highlighted with a "-" in the corresponding cell of the following tables.

Table 1: Factors of mature industrial cluster evolution – Preconditions

Factor	Description	Concept	Key contribution
Labor supply	This precondition contains local labor market aspects, such as a shortage of (skilled) workers as well as a surplus of (skilled) employees and is one of Porter's relevant factor conditions (1990, 1998).	Cluster, Innovative milieu, Industrial district	Isaksen 2018; Mossig & Schieber 2016; Schmidt et al. 2020a;
Universities and research institutes	Universities and public research institutes are relevant infrastructure, provide education and often function as cooperation partners. They are relevant in attraction, training and further education of highly qualified specialists and experts (Mudambi et al., 2017; Porter, 1990, 1998)	Cluster, Innovative milieu	Hu & Hassink 2018; Isaksen 2018; Tödtling & Trippl 2010; Trippl & Otto 2009;
Firm structure	Firm structure such as firm size (OEM vs. medium-sized), management form (family ownership vs. external management) or firm age are influencing firms' abilities to adapt to change.	Cluster	Hu & Hassink 2018;
Cooperative environment	A cooperative environment at the cluster level can manifest itself at different levels of interaction. For example, through constructive and respectful interaction among cluster actors, an open culture of discussion or constructive cooperation at the regional-political level.	Italian district derived	Hoffmann et al. 2017; Mossig & Schieber 2016; Schmidt et al. 2020a;
Competitive environment	A competitive environment is characterized by mutual mistrust, resentment and a dismissive attitude between actors of individual companies as well as between different industries at the cluster level.	Italian district derived	Mossig & Schieber 2016; Schmidt et al. 2020a;
Cognitive lock-in	This precondition addresses a world- view or mindset "that might confuse secular trends with cyclical downturns" (Hassink, 2010, p. 452).	Cluster	Hu & Hassink 2018; Isaksen 2018; Zucchella 2006
Political lock-in	Closely related to cognitive lock-ins, political lock- ins are based on an institutional structure, aiming at preserving existing traditional routines and structures (Hassink, 2010). Such institutional structures can consist of networks organizations, political administrations, (lead) firms, trade unions as well as local norms, rules and laws (Hassink, 2010, 2016)	Cluster	Hu & Hassink 2018; Isaksen 2018; Zucchella 2006
Local capital market	The availability of financial resources to foster innovative activities of firms, transformation processes and spin-offs.	Cluster	-
Hard location factors	This precondition includes regional laws, transportation and childcare infrastructure, taxation, commercial space availability and the housing market.	Cluster	Hu & Hassink 2018;
Soft location factors	The level of education, the availability of recreational activities, access to nature, cultural offerings and the overall quality of life are important regional factors to attract and retain workers from outside the region (Garnsey, 1998; Sternberg & Tamásy, 1999). With an increasing labor shortage, the previous focus on skilled workers could weaken since a general labor shortage (including unqualified labor positions and positions requiring vocational training as well) is expected.	Cluster derived	-

Source: *Authors' own illustration.*

Table 2: Factors of mature industrial cluster evolution – Triggering events

Factor	Description	Concept	Key contribution
Industry restructuring	The reshaping of industries is an event which is often not initiated by one single change in technology. This includes large scale developments like the shift to fordistic mass production, large scale privatizations, the ongoing shift of production units to low wage countries or globalization in general.	Cluster derived, Industrial district derived	Harris 2021; Mossig & Schieber 2016; Zucchella 2006
External market changes	This event includes powerful new trends and related changing consumer habits which result in a changing consumer demand. This includes sector-specific changes (e.g. fashion changes in the textile sector) as well as overlapping developments such as the global shift towards greater sustainability, which influences multiple markets.	Cluster derived, Industrial district derived	Carli & Morrison 2018;
Regulation changes	This event includes regulations changes on international, national and regional level, which let to large scale adaptations on firm level. For example, the medical device regulation implemented by the EU is such a regulation with a disruptive character which influences regional industrial clusters (König, 2023).	Cluster	-
Disruptive innovations	Extensive and ground-braking innovations cause successive development that leads to renewal or decline of a local industrial cluster (Tappi, 2005).	Cluster	Carli & Morrison 2018;
Historical events	Historical events, such as wars, recessions or sudden natural disasters are repeatedly described in case studies as triggering events for renewal or decline of local clusters.	Cluster	Hu & Hassink 2018;
Re-location of lead firm(s)	Since a successful lead firm can be the starting point for the formation of an entire cluster (Wolfe & Gertler, 2004) opposite negative effects seem plausible as soon as a lead firm is re-located.	Cluster derived	Hu & Hassink 2018; Tödtling & Trippl 2010; Trippl & Otto 2009; Zucchella 2006
Re-structuring of lead firm(s)	As described in case studies, extensive restructuring processes of lead firms can cause effects similar to the re-location of a lead firm. This includes staff reduction, organizational restructuring or changes in the structure of the firm ownership	Cluster derived	Tödtling & Trippl 2010; Trippl & Otto 2009;

Source: *Authors' own illustration.*

Table 3: Factors of mature industrial cluster evolution – Self-augmenting processes

Factor	Description	Concept	Key contribution
Training of employees	Due to the fact that Germany has a specific apprenticeship system that differs from other countries, this process includes not only the combination of practical on-the-job training in the firm and teaching at the vocational school, but also further apprenticeship forms. Alongside further training and external recruiting, the training of employees is regarded as a key component to avoid skill shortages in a tight labor market.	Industrial district derived	Schmidt et al. 2020a;
Further education of employees	Further education includes vocational measures such as professional training courses as well as language courses, catching up on school-leaving qualifications or leisure-oriented educational offers. In-firm education, as part of further education of employees, accounts for the largest share. It is characterized by the fact that the measure is supported by the firm.	Industrial district derived	Schmidt et al. 2020a;
External recruiting of employees	In general, external recruitment is necessary if vacant positions cannot be filled with existing firm employees. This process addresses the regional cluster level instead of the inter-firm level (e.g. labor poaching). Therefore, external recruiting includes all hiring processes exceeding the regional labor pool.	Industrial district derived	-
Buyer-Supplier relations	This process addresses the interaction of buyer and supplier firms in one region. It is based on Marshall's (1920) argument that similar firms of one industry located in the same area attract suppliers to the same location. Re-location or firm closings can have negative impact on local supply chains. It is also related to Porter's demand conditions, which are interpreted as foundation of buyer-supplier relations (1990, 1998). This factor can be seen as part of a functional lock-in.	Cluster, Industrial district	Isaksen 2018; Tödtling & Trippl 2010; Trippl & Otto 2009;
Diversification	This process focusses on the expansion of products or services to new markets including the (lead) firm level as well as the cluster level. Aspects of human resource management are not included.	Cluster	Carli & Morrison 2018; Hu & Hassink 2018; Tödtling & Trippl 2010; Trippl & Otto 2009;
Specialization	Focusing on a limited range of products or services in order to be more efficient and to provide a comparative advantage on firm level as well as on cluster level.	Cluster	Hu & Hassink 2018; Isaksen 2018; Mossig & Schieber 2016; Tödtling & Trippl 2010; Trippl & Otto 2009; Zucchella 2006
Outsourcing	Shifting of the company's value-added activities, including products as well as services, to suppliers outside the regional cluster.	Cluster derived	-

Table 3: (continued)

Factor	Description	Concept	Key contribution
Mergers and acquisitions	The process includes both the merger of two companies into one legal entity and the acquisition of business units. All other related aspects of such a process are included. Both, mergers and acquisitions of firms within the regional cluster and of clustered firms with foreign companies are addressed.	Cluster derived	-
Foreign direct investment	The process of cross-border investments by firms or governments in firms of a regional cluster are not part of the financing-precondition since foreign direct investments are a key element of international economic connection between companies and the type of investment is focused on.	Cluster	Carli & Morrison 2018; Tödtling & Trippl 2010; Trippl & Otto 2009; Zucchella 2006
Formation of firms	This process includes multiple foundation associated processes such as entirely new start-ups, spin-offs generated by existing firms, spin-offs of subsidiaries comprising entire company divisions and the privatization of state-owned enterprises. Based on scientific findings that spin-offs in general positively influence cluster development (for example Håkanson, 2005; Klepper, 2006) it can be assumed that the absence of such spin-offs might lead to negative effects such as cluster decline.	Cluster derived	Harris 2021; Mossig & Schieber 2016; Tödtling & Trippl 2010; Trippl & Otto 2009;
Cooperative interaction	Across all relevant theoretical approaches, cooperation is one of the most named factors (…). This process partly overlaps with buyer–supplier relations between firms (see above) and the process of internal knowledge transfer within the cluster because cooperation often involves a transfer of knowledge. This process partly overlaps with the precondition *Cooperative environment.*	Cluster, Industrial district, Innovative milieu	Hoffmann et al. 2017; Mossig & Schieber 2016; Schmidt et al. 2020a;
Competitive interaction	As Porter already described (1990, 1998), a process of competitive interaction between firms is a key aspect of an industrial cluster. Firms' strategy, structure and rivalry is one of four main aspects of his model. This process partly overlaps with the precondition *Competitive environment.*	Cluster	Mossig & Schieber 2016; Schmidt et al. 2020a;
Innovative activities	Innovative activities are a key element of all described concepts on local industrial agglomerations. It includes process innovations, product and service innovations as well as social innovations. This process partly overlaps with *external* and *internal knowledge transfers* and the process of *cooperative interaction*, however, are recorded separately, as these processes are often but not exclusively oriented towards innovation. Furthermore, the event of *disruptive innovations* addresses innovations as well, which is focused on the introduction of a disruptive innovation that can be localized in time and brings about strong changes. This factor can be seen as part of a functional lock-in.	Cluster, Innovative milieu	Hoffmann et al. 2017; Hu & Hassink 2018; Tödtling & Trippl 2010; Trippl & Otto 2009;

Table 3: (continued)

Factor	Description	Concept	Key contribution
External knowledge transfer	Any transfer of knowledge from outside the industrial agglomeration into the cluster or district without a further differentiation between intra-industrial and inter-industrial spillovers. This factor can be seen as part of a functional lock-in.	Industrial district derived	Hoffmann et al. 2017; Hu & Hassink 2018; Schmidt et al. 2020a; Tödtling & Trippl 2010; Trippl & Otto 2009; Zucchella 2006
Internal knowledge transfer	Knowledge spillovers are already mentioned by Marshall (1920), who highlighted the exchange of knowledge between actors. Furthermore, they are a key element of the innovative milieu literature (Camagni, 1995). Intended and unintended spillovers between industries are included here. The process of internal knowledge transfer includes intra- and inter-industrial spillovers in one region. There is no differentiation of spillovers accruing between firms of one industry or across different industries. This factor can be seen as part of a functional lock-in.	Industrial district, Innovative milieu	Hoffmann et al. 2017; Mossig & Schieber 2016; Schmidt et al. 2020a; Tödtling & Trippl 2010; Trippl & Otto 2009; Zucchella 2006
Interaction with policy stakeholders	Included interaction between firms and policy stakeholders are bi-directional. Policy makers are influencing cluster development for example via governmental funding programs, emergency loans, credits, and the design of local taxation. However, existing regional industrial clusters can also influence decisions of policy-makers (Etzkowitz & Leydesdorff, 1995; Rabellotti, 1998).	Cluster, Innovative milieu, Italian district	Carli & Morrison 2018; Harris 2021; Hoffmann et al. 2017; Hu & Hassink 2018; Isaksen 2018; Mossig & Schieber 2016; Schmidt et al. 2020a; Tödtling & Trippl 2010; Trippl & Otto 2009;
Interaction with educational institutions	this process specifically relates to the various forms of exchange between firms and the local educational institutions while the above described precondition (Universities and research institutes) only the presence of educational institutions in the region.	Italian district	Hoffmann et al. 2017; Hu & Hassink 2018; Isaksen 2018; Schmidt et al. 2020a; Tödtling & Trippl 2010; Trippl & Otto 2009; Zucchella 2006
Interaction with cultural institutions	This process relates to the various forms of exchange between firms or cluster organizations and the local cultural institutions such as exhibitions.	Innovative milieu	Hoffmann et al. 2017; Schmidt et al. 2020a;

Table 3: (continued)

Factor	Description	Concept	Key contribution
Interaction in (social) networks	As cooperation and various forms of knowledge transfer, processes based on interaction in social networks are perceived to be another key aspect of local industrial clusters across the different development stages.	Italian district	Harris 2021; Isaksen 2018; Schmidt et al. 2020a; Tödtling & Trippl 2010; Trippl & Otto 2009; Zucchella 2006
Gentrification	The Process of gentrification is less focused on the specific displacement of working-class residents by wealthier professionals within a neighborhood. It addresses upward societal transformation of the regional context of an industrial cluster in general and is not understood as an inherently urban process.	Cluster derived	-
Reputation	A negative reputation of a region or a particular regional industrial cluster can influence the recruitment of workers from the supra-regional labor market. This process is closely related to the precondition of soft location factors.	Cluster derived	-

Source: *Authors' own illustration.*

3 Methods and data

Which of the preconditions, triggering events and self-augmenting processes are relevant in the decline or renewal of a local industrial cluster is an empirical question, which has to be analyzed for each cluster separately. In order to obtain transferable results, a descriptive meta-analysis is conducted. In general, a meta-analysis integrates empirical results from different studies which investigated a common research question based on statistical methods (Florax et al., 2002; Timulak, 2009; Wagner & Weiß, 2014). This study combines results of 69 individual empirical case studies, published in 86 publications.

3.1 Data sources

The case studies used in the meta-analysis are collected from two different publication databases, namely Web of Science (original keyword search) and Google Scholar (citation tracking). Using two different databases is crucial in order to avoid a biased output, since one database could favor a specific kind of literature. The search is based on different keyword combinations since various theoretical concepts are included. The following combinations have been used:

- cluster + decline (463)
- cluster + renewal (103)
- cluster + mature (128)
- cluster + radical innovation (39)
- cluster + lock-in (81)
- industrial district decline (103)
- industrial district renewal (31)
- industrial district + radical innovation (5)
- industrial district lock-in (18)

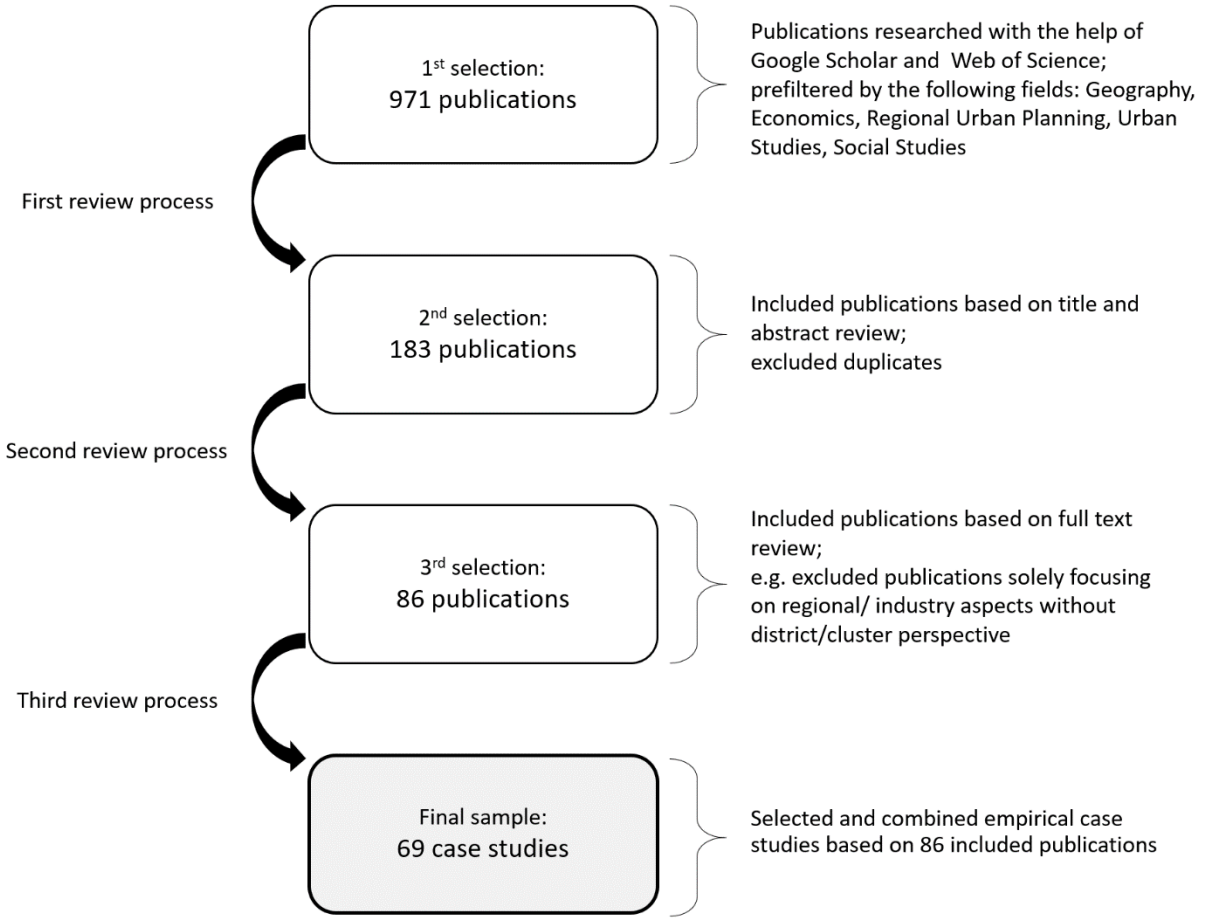
In general, the collection process includes all publications for each search query and not only the most relevant ones. Besides published articles, working papers are included document types to mitigate a publication bias. This broad collection of literature, is followed by different steps based on inclusive criteria: First, the studies are attributed to the following research fields: Geography, Economics, Regional Urban Planning, Urban Studies or Social Sciences Interdisciplinary (Web of Science Categories). Second, the included studies need to be empirical case studies. Industrial studies, regional studies and theoretical articles are collected and documented as well but they are not included in the final sample of the meta-analysis.[5] The findings of the theoretical contributions are included in the theoretical discussion. Third, the analytical focus of the studies needs to be on the specific agglomeration and addresses aspects of decline, renewal, transformation or disruptive innovations. Furthermore, studies focused on lock-ins, resilience or path dependent developments are included as long as they focus on a cluster, Marshallian industrial district or old industrial district. Forth, a separation of the case by administrative boarders is irrelevant as long as geographical proximity is

[5] Industry studies, regional studies and theoretical articles are not collected in their entirety.

granted and the firms and actors are part of one industrial cluster. Last, the case study must provide a sufficient amount of information on the development of the particular case. Based on these inclusive criteria, the case studies are graded.

Figure 2 illustrates the collection process and the creation of the final sample. Overall, 971 studies have been considered in the first selection. After excluding duplicate articles (e.g. working paper and journal article) and a first review process including the title and the abstract, 183 studies remain in the gross sample. Subsequently, two more detailed reviews of the studies are conducted. At the end, the final meta-analysis considers a net sample of 69 empirical case studies which fulfil the inclusion criteria, based on 86 publications.

Figure 2 – Selection process of included case studies



Source: *Authors' own illustration.*

Up to now only a limited number of publications have applied a meta-analysis addressing the phenomena of industrial clusters in general. Most relevant for the context to this study, Brenner and Mühlig (2013) analyzed factors of cluster emergence based on 159 cases, using a similar categorization of influential factors. Further publications are covering a wide range of cluster related topics (Fang, 2015; Fang & Drucker, 2021; Frenken et al., 2015; Grashof & Fornahl, 2021; Maggioni et al., 2009;

Mathias et al., 2021; Melo et al., 2009; Van der Linde, 2003). However, these are not relevant in the context of this study.

3.2 Methodology

Forty-three different preconditions, triggering events and self-augmenting processes were identified and listed above (see Section 2.4). Applying the approach of Brenner and Mühlig (2013), each case study is checked for these potential factors. Since the included case studies are not addressing each possible factor in every case study, the factors are classified for each studied case as follows:

- Class I (important): the author(s) explicitly states that the precondition, event or process is present and important.
- Class U (unimportant): the author(s) explicitly rejects the importance of the precondition, event or process.
- Class N (no information): the case study does not address the importance of the precondition, event or process at all

Furthermore, a differentiation between different stages of cluster evolution is necessary, since clusters 1) are declining after maturity; 2) are successfully renewed after maturity or 3) are first declining and afterwards entering a process of renewal. For the latter case, we additional classify for each factor whether its relevance is stated in the context of decline or renewal:

- Class IDC, IR, or INS (important): the author(s) explicitly states that the precondition, event or process is important and do so in the context of decline, renewal or without stating such a connection.
- Class UDC, UR or UNS (unimportant): the author(s) explicitly states that the precondition, event or process is unimportant and decline/renewal associated or not further specified.
- Class N (no information): the case study does not address the importance of the precondition, event or process at all

By analyzing a case study, it can be classified with respect to each precondition, triggering event and self-augmenting process into one of these classes. As a result, a matrix is obtained in which each row presents a local industrial cluster and each column presents a precondition, event and process. Therefore, each cell of this matrix contains either an…

- … I, a U or an N if the cluster is in a stage of decline or renewal
- … IDC, a UDC or an N if the cluster is first in a stage of decline, afterwards in a stage of renewal and the described precondition, event or process is decline-associated
- … IR, a UR or an N if the cluster is first in a stage of decline, afterwards in a stage of renewal and the described precondition, event or process is renewal-associated
- … INS, a UNS or an N if the cluster is first in a stage of decline, afterwards in a stage of renewal and the described precondition, event or process is not clearly specified

Since some of these potential factors were not mentioned in the case studies, a matrix is obtained that contains numerous N-entries (no information). Ideally, this matrix would only contain I(DC/R/NS)-entries (important) and U(DC/R/NS)-entries (unimportant).

While the import- and unimportant-entries do not require further discussion, the large amount of no-information-entries are in need to be discussed. Two interpretations of these cases are possible: 1) It can be assumed that the case studies focused on factors which were important for the transformation of the specific local industrial cluster they analyzed. As a consequence, factors might not be mentioned because they are seen as unimportant. 2) It can be assumed that the authors of case studies ignore potential factors right from the beginning for various reasons. Due to the two potential explanations, and the no-information-entries have to be interpreted with caution.

Furthermore, specific local industrial cluster were discussed in multiple publications. In these cases, all available case studies were included in order to avoid pre-selection. When the results for a factor varied across the different publications, the following rules were applied:

- If only classes I (IDC, IR, INS) and N appeared, it was classified as I (IDC, IR, INS).
- If only classes I (UDC, UR, UNS) and N appeared, it was classified as U (UDC, UR, UNS).
- All other cases were classified as not N.

Following these rules, all mentioned precondition, triggering event and self-augmenting process of a case study were combined in a comprehensible matter and each case was only considered once. In this way, 69 local industrial clusters were classified on the basis of 86 publications and included in the final sample (for an overview of the sample, see Section 6.1 in the Appendix). A total of forty-three potential factors for the decline, renewal, or renewal of a declining local industrial clusters were identified. According to the presented theoretical aspects, these factors are distinguished between preconditions, triggering events and self-augmenting processes.

Finally, chi-squared tests were used to determine, whether there was a statistically significant correlation between each specific factor and its importance for the decline or renewal of industrial clusters.

4 Empirical results

Before examining the decline and renewal of mature industrial clusters, focusing on preconditions, triggering events and self-augmenting processes involved, it is helpful to take a closer look at the empirical case studies of the final sample and the publications on which they are based.

4.1 Descriptive overview

The first part of the following descriptive overview is based on the 86 publications, analyzing publication dates, theoretical and methodological frameworks and publishing journals. However, since

the analysis in this article is based on empirical case studies, the description of the cluster location and sector distribution in the second part is based on the 69 local industrial clusters.

The publication dates of the empirical case studies range from 2022 to 1993. The majority of the cases were conducted in 2010 and later (70 of the 86 publications). The years with the highest number of publications were 2017/2018 with a total of 32. Thus, the aspects of decline and renewal of industrial clusters have been more recently discussed in the scientific debate - mainly in the research field of regional science and planning.

In terms of the disciplines of the publishing journals, the decline and renewal of industrial clusters is most frequently discussed in the field of Regional Science and Planning (46 publications). This is followed by journals in (economic) geography (15 publications), economics (14 publications) and business studies (9 publications). The most frequently used medium is the peer-reviewed academic article; monographs, edited volumes and working papers are rarely used, but are included. Publications on declining local clusters as well as publications on local clusters where the period of decline has been replaced by a subsequent period of renewal show a comparable publication pattern across journals. Interestingly, when looking at local clusters that entered a phase of renewal without a previous phase of decline, regional science and planning journals almost exclusively publish articles on this aspect.

As different theoretical concepts of industrial agglomeration and different factors of cluster decline and renewal are analyzed, the wording in the case study titles was interpreted as the authors' preference for the respective concept. All cases were therefore classified as follows:

- Cluster-related, if at least one empirical case study has a title containing the word cluster and no study has a title containing any of the other concepts.
- District-related, if at least one empirical case study has a title containing the word district and no study has a title containing one of the other concepts. This includes Marshallian industrial districts and old industrial districts.

It was found that 63 publications were cluster related and 23 publications were district related.[6] Interestingly, publications analyzing three empirical case studies used both concepts. Other theoretical aspects (see section 2.2.3), such as path dependencies, lock-ins or resilience, were not sufficiently frequent to be analyzed and these publications could be assigned to the superordinate concepts (cluster/district). Methodologically, the case study publications are, not surprisingly, characterized by the frequent use of qualitative interviews. Secondary data analysis is sometimes also used.

Overall, most industrial clusters decline after reaching the stage of maturity. While 22 of the 69 cases analyzed entered a stage of renewal after the previous stage of decline, 15 industrial clusters were

[6] Only in a very limited number of cases did the title of the publication not clearly indicate the underlying theoretical concept. A full review was then carried out to identify the underlying concept.

able to renew themselves directly without a previous stage of decline. In terms of case study countries (see Table 4), the majority of the 69 local industrial clusters are located in European countries (52 cases), mainly in Germany, England and Italy. This is followed by countries in the Americas (11 cases) and Asian countries (6 cases); case studies from African countries or Australia could not be part of the analysis as the sample did not include case studies from these countries.

Table 4: Case study countries

		Decline	Renewal	Dec & Ren	Total
Europe	Austria	0	1	2	3
	Belgium	0	1	0	1
	Denmark	1	0	0	1
	England	6	1	2	9
	Finland	0	0	2	2
	France	0	1	0	1
	Germany	6	2	2	10
	Italy	5	1	3	9
	Norway	2	3	1	6
	Scotland	1	1	0	2
	Spain	0	1	0	1
	Sweden	2	1	2	5
	Turkey	1	0	1	2
Americas	Brazil	1	0	0	1
	Canada	2	1	0	3
	Chile	0	0	1	1
	USA	3	0	3	6
Asia	China	0	0	1	1
	Japan	2	0	1	3
	South Korea	1	1	0	2
		33	**15**	**21**	**69**

Source: *Authors' own illustration based on the analyzed empirical case studies.*

In terms of sectoral distribution (see Table 5), the most frequent sectors overall are textiles (10 cases), automobiles (9 cases), energy (8 cases), ceramics, furniture and ICT (7 cases each). When broken down by stage of development, almost all of the cases in the textiles, ceramics, shipbuilding and footwear sectors are associated with cluster decline, which is not surprising as clusters in these industries tend to be older. By contrast, the second and third most common sectors, automotive and energy, were more often able to renew themselves, either directly or after a period of decline. Again, these results are not surprising as the automotive and energy clusters are younger clusters.

Table 5: Sector distribution

	Decline	Renewal	Dec & Ren	Total
Agriculture/Food/Beverages	0	1	0	1
Automotive	3	2	4	9
Ceramics	4	1	2	7
Chemistry	0	1	0	1
Culture	1	0	0	1
Energy	3	4	1	8
Footwear	3	0	1	4
Furniture/Jewellery/Musical instruments	2	1	4	7
High-Tech	1	0	0	1
ICT	4	1	2	7
Manufactoring/Engineering	1	2	2	5
Maritme Industries	0	1	0	1
Metals	1	0	2	3
Shipbuilding	3	1	0	4
Textile	7	0	3	10
	33	**15**	**21**	**69**

Source: *Authors' own illustration based on the analyzed empirical case studies.*

4.2 Decline and Renewal: Preconditions, events and processes

In regard to the research question, the preconditions, triggering events and self-augmenting processes mainly include relevant important factors. Factors that are mentioned but at the same time described as unimportant are rare, and other potentially relevant factors are usually not discussed, which explains the frequent use of the no-information category and the rare use of the unimportant-category. For this reason, these categories are not discussed further below, and important is always compared with the other two combined categories (unimportant and no information) in all statistical analyses.

In terms of the preconditions included, it was found that for each of the 69 local industrial clusters, an average of three preconditions were identified as important. The number of preconditions varies between zero and a maximum of nine out of a total of eleven factors. Therefore, preconditions seem to be relevant for the development of clusters according to their stage of maturity. However, the relevance of each of the preconditions varies considerably: while the *firm structure* is the most frequently mentioned precondition (41 cases), the *cooperative environment* (5 cases) is less relevant. Considering the different importance of each precondition for the decline or renewal of a cluster, most of the preconditions can be assigned to one of the stages. The following preconditions show statistically significant results according to a chi-squared test. Focusing on decline, a *cognitive lock-in* and a *competitive environment* are relevant preconditions. Focusing on renewal, *universities and research institutes* are most relevant for the revitalization of a regional cluster. Interestingly, most of

the preconditions are relevant to both decline and renewal, while only three preconditions are clearly associated with either decline or renewal. Further results for each precondition are shown in Table 6.

Table 6: Frequencies of preconditions

Precondition	Important				Unimportant / No Information				Chi-squared test
	DEC	REN	NS	SUM	DEC	REN	NS	SUM	
Firm structure	22	14	5	41	27	18	0	45	0,010 (3,841)
Hard location factors	12	15	1	28	41	21	0	62	3,672 (3,841)
Labor supply	12	6	2	20	40	29	0	69	0,449 (3,841)
Cognitive lock-in	16	4	0	20	38	33	0	71	4,535 (3,841)
Universities and research inst.	6	10	3	19	45	24	0	69	4,158 (3,841)
Competitive environment	13	3	0	16	41	34	0	75	3,862 (3,841)
Local capital market	4	5	1	10	49	31	0	80	0,949 (3,841)
Political lock-in	8	2	0	10	46	35	0	81	1,987 (3,841)
Soft location factors	6	4	0	10	48	33	0	81	0,002 (3,841)
Cooperative environment	3	1	1	5	50	35	0	85	0,415 (3,841)

Note: *Significance level of 5 %, degree of freedom d(f) of 1, critical values of chi-square distribution of 3,841. If the chi-squared value exceeds the corresponding critical value of 3.841, a statistically significant correlation between the respective factor and its relevance for cluster evolution (decline vs. renewal) can be assumed.*
Source: *Authors' own illustration based on the analyzed empirical case studies.*

Compared to the previous preconditions and the following self-augmenting processes, the triggering events have been less discussed in the literature. Although, the list of triggering events is significantly shorter, the individual events were mentioned just as often, with an average of two important events identified per case. While *industrial restructuring* was the most frequently identified event, the *re-location of a lead-firm* was the least frequently mentioned. Overall, the majority of the triggering events are much more likely to be associated with the decline of an industrial cluster, especially *industrial restructuring events* and *historical events* as well as *external market changes* due to their statistically significant results.

Table 7: Frequencies of triggering events

Triggering event	Important				Unimportant / No Information				Chi-squared test
	DEC	REN	NS	SUM	DEC	REN	NS	SUM	
Industry restructuring	31	8	0	39	22	29	0	51	12,062 (3,841)
Historical events	21	3	0	24	33	34	0	67	10,713 (3,841)
Regulation changes	16	5	0	21	38	32	0	51	3,212 (3,841)
Disruptive innovations	13	5	0	18	41	32	0	73	1,543 (3,841)
Re-structuring of lead firm(s)	8	9	0	17	46	28	0	74	1,307 (3,841)
External market changes	15	1	0	16	39	36	0	75	9,527 (3,841)
Re-location of lead firm(s)	5	7	0	12	49	30	0	79	1,790 (3,841)

Note: *Significance level of 5 %, degree of freedom d(f) of 1, critical values of chi-square distribution of 3,841. If the chi-squared value exceeds the corresponding critical value of 3.841, a statistically significant correlation between the respective factor and its relevance for cluster evolution (decline vs. renewal) can be assumed.*
Source: *Authors' own illustration based on the analyzed empirical case studies.*

At the spatial level, these events are supra-regional, influencing entire sectors or markets across national borders. In contrast, location-related events at the regional level are more evenly distributed between the decline and renewal of industrial clusters. All frequencies of triggering events are listed in Table 7 above.

The self-augmenting processes were much more widely discussed in the literature (see Table 8). There was only one local cluster where none of the self-augmenting processes was mentioned as an important cause for the decline or renewal of the clusters. In comparison, there were six cluster where none of the preconditions and triggering events were found.

Table 8: Frequencies of self-augmenting processes

Self-augmenting process	Important				Unimportant / No Information				Chi-squared test
	DEC	REN	NS	SUM	DEC	REN	NS	SUM	
Interaction with policy stakehold.	15	23	0	38	39	14	0	53	10,673 (3,841)
Competitive interaction	22	13	0	35	32	24	0	56	0,291 (3,841)
Innovation activities	13	21	0	34	41	16	0	57	10,021 (3,841)
Formation of firms	10	22	0	32	44	15	0	59	16,142 (3,841)
Interaction in (social) networks	9	21	0	30	44	15	1	60	16,406 (3,841)
Specialization	16	10	1	27	36	25	1	62	0,048 (3,841)
Internal knowledge transfer	5	20	0	25	49	17	0	66	22,111 (3,841)
Interaction with educational inst.	8	15	0	23	46	22	0	68	7,694 (3,841)
Buyer-Supplier relations	8	12	2	22	44	23	0	67	4,221 (3,841)
Cooperative interaction	5	15	0	20	48	21	1	70	12,784 (3,841)
Diversification	6	13	0	19	47	23	1	71	7,847 (3,841)
External knowledge transfer	4	10	0	14	50	27	0	77	6,492 (3,841)
Outsourcing	5	7	0	12	49	30	0	79	1,790 (3,841)
Foreign direct investment	2	9	0	11	52	28	0	80	8,785 (3,841)
Reputation	2	8	0	10	52	29	0	81	7,207 (3,841)
Mergers and acquisitions	7	2	0	9	47	35	0	82	1,407 (3,841)
External recruiting of employees	2	5	0	7	52	32	0	84	2,976 (3,841)
Further education of employees	2	4	0	6	52	33	0	85	1,801 (3,841)
Training of employees	2	3	0	5	52	34	0	86	0,820 (3,841)
Interaction with cultural inst.	0	2	0	2	54	35	0	89	2,985 (3,841)
Gentrification	1	0	0	1	53	37	0	90	0,693 (3,841)

Note: *Significance level of 5 %, degree of freedom d(f) of 1, critical values of chi-square distribution of 3,841. If the chi-squared value exceeds the corresponding critical value of 3.841, a statistically significant correlation between the respective factor and its relevance for cluster evolution (decline vs. renewal) can be assumed.*
Source: *Authors' own illustration based on the analyzed empirical case studies.*

Often several of the identified processes are relevant at the same time, on average five per local cluster. In particular, several self-augmenting processes have a statistically significant influence on the renewal of industrial clusters. In contrast, only four processes seem to be associated more frequently with the decline of a cluster: *specialization*, *competitive interaction, mergers and acquisitions* and *gentrification.* However, these differences are not statistically significant. In particular, processes that involve a high degree of interaction between the related actors are the most relevant in the context of cluster renewal (e.g. *interaction with policy stakeholders, formation of firms, interaction in (social)*

networks, innovation activities, internal knowledge transfer, interaction with educational institutions, and *cooperative interaction*).

In summary, the above analysis shows that both the decline and renewal of an industrial cluster are driven by specific preconditions and self-augmenting processes and the used classification of factors – inspiered by a meta-study on the emergence of clusters – is transferable (Brenner & Mühlig, 2013). Furthermore, clusters are not isolated entities and are shaped by external influences, such as triggering events (Carli & Morrison, 2018; Martin & Sunley, 2011). Across all local clusters, preconditions were identified as important 184 times, while triggering events were described as important a total of 141 times. However, self-augmenting processes appear to be more relevant: across all the clusters included, the 22 factors analysed are mentioned as important 382 times. Furthermore, the factors change over time and can have both positive and negative dimensions: a factor that has a negative influence on cluster decline can change its form, take on a different characteristic and have a positive influence on cluster renewal.

The decline of industrial clusters is more often associated with unfavourable preconditions and triggering events at the sector or market level. The results prove, that booth, lock-ins (Isaksen, 2018) and path dependencies (Mossig & Schieber, 2016) are helpful concepts and are often attributed to the decline of clusters. Self-augmenting processes, on the other hand, are more often found in the context of cluster renewal, which is not surprising, as self-augmenting processes also play a crucial role in the emergence of clusters. They are a constitutive feature of clustering and renewal can be seen as re-emergence (Brenner & Mühlig, 2013). In particular, the following factors play a key role both in the current context of renewal and in the emergence of clusters: *universities and research institutes, cooperative interaction, interaction with policy stakeholders, formation of firms*, *innovation activities, internal knowledge transfer, interaction with educational institutions, and buyer-supplier relations*.

Surprisingly, preconditions and processes, that are mainly associated with the reduction of skill shortages – such as *labor supply*, *external recruiting*, *further education*, and *training of employees* – are so far not often associated with the decline or renewal of an industrial cluster. Nor do they have a significant impact on cluster development. On the one hand, the low relevance of these factors could be related, among other things, to the attractiveness of clusters as business locations: the results show that firms located in industrial clusters are significantly less likely to experience skill shortages. At the same time, the ratio of unfilled qualified labor positions increases for clustered firms that already report skill shortages (König & Brenner, 2022). On the other hand, declining and potentially failing clusters may suffer more from various other negative factors, which are therefore more present.

5 Conclusion

While the emergence and evolution of industrial clusters has been extensively analyzed, aspects of decline and renewal have only recently attracted the attention of the academic debate. Therefore, this article discusses the phenomenon of industrial cluster decline and renewal, focusing on enabling factors. These factors are divided into preconditions, triggering events and self- augmenting processes. Building on recent literature, this meta-study aimed to broaden aspects of mature industrial cluster development, which has been largely dominated by case study literature. Inspired by Brenner and Mühlig's (2013) analysis, which focuses on the emergence of industrial clusters, this article transfers this approach to cluster decline and renewal by analyzing the existing case studies on this topic.

With regard to the research question, the empirical results of this study show that both the decline and the renewal of an industrial cluster are driven by specific preconditions, triggering events and self-augmenting processes, which differ between the stages of development. Thus, while these basic factors may be present in both positive and negative dimensions and may change over time, but the decline of industrial clusters is more often associated with the influence of unfavorable regional preconditions and triggering events at the sectoral, market or country level, while several self-augmenting processes are more often found in the context of cluster renewal. In particular, processes involving a high degree of interaction between the actors involved are most relevant in the context of cluster renewal. Across all local clusters, preconditions were identified as important 184 times, while triggering events were described as important a total of 141 times. Clusters are therefore shaped by external influences and are not isolated entities. However, self-augmenting processes appear to be of greater relevance: across all the clusters included, the 22 processes analyzed are mentioned 382 times.

Overall, the results show that processes that have been discussed several times in publications dealing with factors in the development of mature industrial clusters or districts are more often identified as important. Self-augmenting processes play a crucial role in both in the emergence of clusters and in their renewal once they have reached maturity (Brenner & Mühlig, 2013). Although the EEG and the regional studies have provided multiple case studies and different theoretical concepts, including factors influencing the evolution of mature industrial clusters and districts, several issues remain unsolved (Hu & Hassink, 2018) and a multiscalar approach is needed to better account for all relevant factors into account (Carli & Morrison, 2018).

This study has limitations. Firstly, the results are based on the frequencies of the factors analyzed. This methodological approach is suitable for providing a basic overview of the preconditions, events and processes involved. However, these are not statistically significant results that would allow us to identify clear relationships between specific factors. Secondly, this area of research is relatively new

and the meta-study would benefit from a larger number of publications analyzed. For both case studies and theoretical framework publications together, the number of published articles increases slowly in the early 2000s and peaks in 2018. After that, the number starts to decrease again. Thirdly, the case studies analyzed are mainly from European countries. While a significantly smaller number of case studies from the Americas and Asia are included, results from the African continent and Australia are completely missing. As a result, the findings are European-centered and have limited applicability to industrial clusters worldwide.

Based on the existing literature and the results of this study, the following policy recommendation can be formulated. Since the results show that the renewal of industrial clusters is strongly influenced by self-augmenting processes, regional economic policy should shape local preconditions in such a way that these processes can develop optimally. In particular, most of the preconditions often identified as important can also be influenced by regional economic policy measures. In times of a growing skill shortages and a drastic ageing of the workforce, the improvement of hard location factors, the supply of labor and the establishment of universities and research institutes should be promoted even more strongly by regional economic policy.

6 Appendix

6.1 Publications in the final sample

The publications included in the final sample are presented in tabular form (see Appendix, Table 9).

6.2 Data Availability Statement

The data that support the findings of this study are partly available on request from the corresponding author. The general privacy restrictions apply.

Table 9: Publications in the final sample

Authors	Title	Year	Journal	Concept
Albors-Garrigos, Jose; Hervas-Oliver, Jose Luis	Creative Destruction in Clusters: From Theory to Practice, the Role of Technology Gatekeepers, Understanding Disruptive Innovation in Industrial Districts	2014	Working Paper (Picmet)	Cluster
Albors-Garrigos, Jose; Hervas-Oliver, Jose Luis	Disruptive Innovation in Traditional Clusters: The Case of the Kerajet Ceramic Tile Cluster in Spain	2019	Applied Sciences	Cluster
Andiani, Pierpaolo; Siedlok, Frank	The collapse and regeneration of complex clusters: some evolutionary considerations	2007	Working Paper (Druid)	Cluster
Arbuthnott, Andrew; Friedrichs, Yvonne von	Entrepreneurial renewal in a peripheral region: the case of a winter automotive-testing cluster in Sweden	2013	Entrepreneurship & Regional Development	Cluster
Bellandi, Marco; De Propris, Lisa; Santini, Erica	An Evolutionary Analysis of Industrial Districts: The Changing Multiplicity of Production Know-How Nuclei	2019	Cambridge Journal of Economics	Industrial District
Bellandi, Marco; Santini, Erica; Vecciolini, Claudia	Learning, unlearning and forgetting processes in industrial districts	2018	Cambridge Journal of Economics	Industrial District
Buciuni, Giulio; Pisano, Gary	Knowledge integrators and the survival of manufacturing clusters	2018	Journal of Economic Geography	Cluster
Carli, Giulio; Morrison, Andrea	On the evolution of the Castel Goffredo hosiery cluster: a life cycle perspective	2018	European Planning Studies	Cluster
Chaminade, Cristina; Bellandi, Marco; Plechero, Monica; Santini, Erica	Understanding processes of path renewal and creation in thick specialized regional innovation systems. Evidence from two textile districts in Italy and Sweden	2019	European Planning Studies	Industrial District
Chapman, Keith; MacKinnon, Danny; Cumbers, Andrew	Adjustment or renewal in regional clusters? A study of diversification amongst SMEs in the Aberdeen oil complex	2004	Royal Geographical Society	Cluster
Comunian, Roberta; England, Lauren	The resilience of knowledge from industrial to creative clusters: the case of regional craft clusters in the West Midlands (UK)	2018	Article in edited volume	Cluster
Comunian, Roberta; England, Lauren	Creative clusters and the evolution of knowledge and skills: From industrial to creative glassmaking	2019	Geoforum	Cluster
Denney, Steven; Southin, Travis; Wolfe, David A.	Entrepreneurs and cluster evolution: the transformation of Toronto's ICT cluster	2021	Regional Studies	Cluster

Table 9: (continued)

Authors	Title	Year	Journal	Concept
Diaz-Perez, Claudia; Wixted, Brian; Holbrook, Adam J.	Vancouver's fuel cell cluster: new opportunities or a genteel decline?	2018	Article in edited volume	Cluster
Evren, Yiğit; Ökten, Ayşe Nur	Stickiness and slipperiness in Istanbul's old city jewellery cluster: a survival story	2017	Journal of Economic Geography	Cluster
Fai, Felicia; Tomlinson, Philip; Branston, Robert	Actors, knowledge and path transformations in a declining cluster	2022	European Urban and Regional Studies	Cluster
Felzensztein, Christian; Gimmon, Eli; Deans, Kenneth R.	Coopetition in regional clusters: Keep calm and expect unexpected changes	2018	Industrial Marketing Management	Cluster
Fløysand, Arnt; Njøs, Rune; Nilsen, Trond; Nygaard, Vigdis	Foreign direct investment and renewal of industries: framing the reciprocity between materiality and discourse	2017	European Planning Studies	Cluster
Frank, Stephanie	A tale of the last two film row districts: historic preservation and urban design in Kansas City and Oklahoma City	2019	Journal of Urban Design	Industrial District
Grabher, Gernot	The weakness of strong ties. The lock-in of regional development in the Ruhr area	1994	Article in edited volume	Industrial District
Grillitsch, Markus; Asheim, Björn	Cluster policy: Renewal through the integration of institutional variety	2017	Article in edited volume	Cluster
Grillitsch, Markus; Rekers, Josephine	Selection and cluster evolution: A conceptual and empirical investigation using the case of Med-Tech	2014	Working Paper (Druid)	Cluster
Hannigan, Thomas J.; Cano-Kollmann, Marcelo; Mudambi, Ram	Thriving innovation amidst manufacturing decline: the Detroit auto cluster and the resilience of local knowledge production	2015	Industrial and Corporate Change	Cluster
Hassink, Robert	The Strength of Weak Lock-Ins: The Renewal of the Westmünsterland Textile Industry	2007	Environment and Planning A	Cluster / Industrial District
Hassink, Robert	Locked in decline? On the role of regional lock-ins in old industrial areas	2010	Article in edited volume	Industrial District
Hervas-Oliver, Jose Luis; Albors-Garrigos, Jose	Are technology gatekeepers renewing clusters? Understanding gatekeepers and their dynamics across cluster life cycles	2014	Entrepreneurship & Regional Development	Cluster
Hervas-Oliver, Jose-Luis; Albors-Garrigos, Jose	Are technological gatekeepers constraining my cluster? Unfolding the paradox of gatekeepers resilience across cluster life cycle stages	2013	Working Paper	Cluster

Table 9: (continued)

Authors	Title	Year	Journal	Concept
Hervás-Oliver, Jose-Luis; Albors-Garrigos, Jose; Estelles-Miguel, Sofia; Boronat-Moll, Carles	Radical innovation in Marshallian industrial districts	2018	Regional Studies	Industrial District
Hodson, Mike	Old Industrial Regions, Technology, and Innovation: Tensions of Obduracy and Transformation	2008	Environment and Planning A	Industrial District
Isaksen, Arne	From success to failure, the disappearance of clusters: a study of a Norwegian boat-building cluster	2018	Cambridge Journal of Regions, Economy and Society	Cluster
Jaegersberg, Gudrun; Ure, Jenny	The German Case: A Cluster Under Threat	2017	Article in edited volume	Cluster
Johns, Jennifer	The role of lead firms in cluster evolution: The case of the Manchester television cluster	2016	Norsk Geografisk Tidsskrift	Cluster
Kagami, Mitsuhiro	Iron town cluster: Yawata, its glory, decline and rebirth	2007	Article in edited volume	Cluster
Lazzeretti, Luciana; Capone, Francesco	Cluster evolution in mature Industrial cluster. The case of Prato Marshallian ID after the entrance of Chinese firm populations (1945-2011)	2014	Working Paper (ERSA)	Cluster
Lazzeretti, Luciana; Capone, Francesco	The transformation of the Prato industrial district: an organisational ecology analysis of the co-evolution of Italian and Chinese firms	2017	The Annals of Regional Science	Industrial District
Martin, Roman; Trippl, Michaela	The evolution of the ICT cluster in southern Sweden – regional innovation systems, knowledge bases and policy actions	2017	Geografiska Annaler: Series B, Human Geography	Cluster
Molina-Morales, Francesc Xavier; Martínez-Cháfer, Luis; Valiente-Bordanova, David	Disruptive Technological Innovations as New Opportunities for Mature Industrial Clusters. The Case of Digital Printing Innovation in the Spanish Ceramic Tile Cluster	2017	Investigaciones Regionales - Journal of Regional Research	Cluster
Mossig, Ivo; Schieber, Lars	Driving forces of cluster evolution – Growth and lock-in of two German packaging machinery clusters	2016	European Urban and Regional Studies	Cluster
Mudambi, Ram; Mudambi, Susan; Mukherjee, Debmalya; Scalera, Vittoria	Global Connectivity and the Evolution of Industrial Clusters: From Tires to Polymers in Northeast Ohio	2017	Working Paper	Cluster
Njøs, Rune; Orre, Lina; Fløysand, Arnt	Cluster renewal and the heterogeneity of extra-regional linkages: a study of MNC practices in a subsea petroleum cluster	2017	Regional Studies, Regional Science	Cluster

Table 9: (continued)

Authors	Title	Year	Journal	Concept
Østergaard, Christian Richter; Park, Eunkyung	What Makes Clusters Decline? A Study on Disruption and Evolution of a High-Tech Cluster in Denmark	2015	Regional Studies	Cluster
Öz, Özlem; Özkaracalar, Kaya	What Accounts for the Resilience and Vulnerability of Clusters? The Case of Istanbul's Film Industry	2011	European Planning Studies	Cluster
Pinkse, Jonatan; Vernay, Anne-Lorène; D'Ippolito, Beatrice	An organisational perspective on the cluster paradox: Exploring how members of a cluster manage the tension between continuity and renewal	2018	Research Policy	Cluster
Potter, Antony; Watts, H. Doug	Revisiting Marshall's Agglomeration Economies: Technological Relatedness and the Evolution of the Sheffield Metals Cluster	2014	Regional Studies	Cluster
Propris, Lisa de; Lazzeretti, Luciana	Measuring the Decline of a Marshallian Industrial District: The Birmingham Jewellery Quarter	2009	Regional Studies	Industrial District
Rafiqui, Pernilla S.	Recounting a Cluster Life Cycle. A century of furniture production in Virserum, Sweden	2010	Working Paper	Cluster
Santner, Dominik	Cluster-internal and external drivers of cluster renewal: evidence from two German agricultural engineering case studies	2018	European Planning Studies	Cluster
Schmidt, Vitor; Carneiro Zen, Aurora; Bittencourt, Brunde Anicet; Engelman Machado, Raquel	Cluster Life Cycle: A Study in the Vale dos Sinos Footwear Cluster	2020	Revista de Negócios	Cluster
Schmidt, Vitor Klein; dos Santos, Diego Alex Gazaro; Zen, Aurora Carneiro; Bittencourt, Bruno Anicet; Belussi, Fiorenza	Trajectory Dependence, Lock-In Effect, and Cluster Decline: A Case Study of the Footwear Cluster in Sinos-Paranhana Valley	2020	Latin American Business Review	Cluster
Scott, Allen J.	The changing fortunes and future prospects of a traditional industrial cluster: Woollen textile production in the Scottish Borders	2022	Local Economy	Cluster
Sedita, Silvia Rita; Ozeki, Tamane	Path renewal dynamics in the Kyoto kimono cluster: how to revitalize cultural heritage through digitalization	2021	European Planning Studies	Cluster
Staber, Udo	Specialization in a Declining Industrial District	1997	Growth and Change	Industrial District

Table 9: (continued)

Authors	Title	Year	Journal	Concept
Staber, Udo	Spatial Proximity and Firm Survival in a Declining Industrial District: The Case of Knitwear Firms in Baden-Wuerttemberg	2001	Regional Studies	Industrial District
Swalens, Maud; McLean, Aldo; Helms, Marilyn	Can cluster survive: A case study of the flooring industry´s evolution	2020	Journal of Competitiveness Studies	Cluster
Sweeney, Brendan; Mordue, Greig;	Resilient or resistant? Critical reflections on resilience in an old	2020	Geoforum	Industrial District
Tappi, Deborah	Clusters, Adaptation and Extroversion. A Cognitive and Entrepreneurial Analysis of the Marche Music Cluster	2005	European Urban and Regional Studies	Cluster
Tödtling, Franz; Trippl, Michaela	Like Phoenix from the Ashes? The Renewal of Clusters in Old Industrial Areas	2004	Urban Studies	Cluster
Tomlinson, Philip R.; Branston, J. Robert	Turning the tide: prospects for an industrial renaissance in the North Staffordshire ceramics industrial district	2014	Cambridge Journal of Regions, Economy and Society	Industrial District
Treado, Carey Durkin	Pittsburgh's evolving steel legacy and the steel technology cluster	2010	Cambridge Journal of Regions, Economy and Society	Cluster
Trippl, Michaela; Otto, Anne	How to Turn the Fate of Old Industrial Areas: A Comparison of Cluster-Based Renewal Processes in Styria and the Saarland	2009	Environment and Planning A	Cluster
Vanthillo, Ties; Cant, Jeroen; Vanelslander, Thierry; Verhetsel, Ann	Understanding evolution in the Antwerp chemical cluster: the role of regional development strategies	2018	European Planning Studies	Cluster
Vinczse, Zsuzsanna; Teräs, Jukka	Mechanisms of Innovation-Based Cluster Transformation	2016	Article in edited volume	Cluster
Yamamura, Eiji	Dynamics of social trust and human capital in the learning process: The case of the Japan garment cluster in the period 1968–2005	2009	Journal of Economic Behavior & Organization	Cluster
Yang, Xueke; Xu, Honggang; Ni, Sisi	The creative renewal of a craft cluster: the role of materiality and mobility in cluster evolution	2020	Regional Studies	Cluster

Source: *Authors' own illustration.*

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