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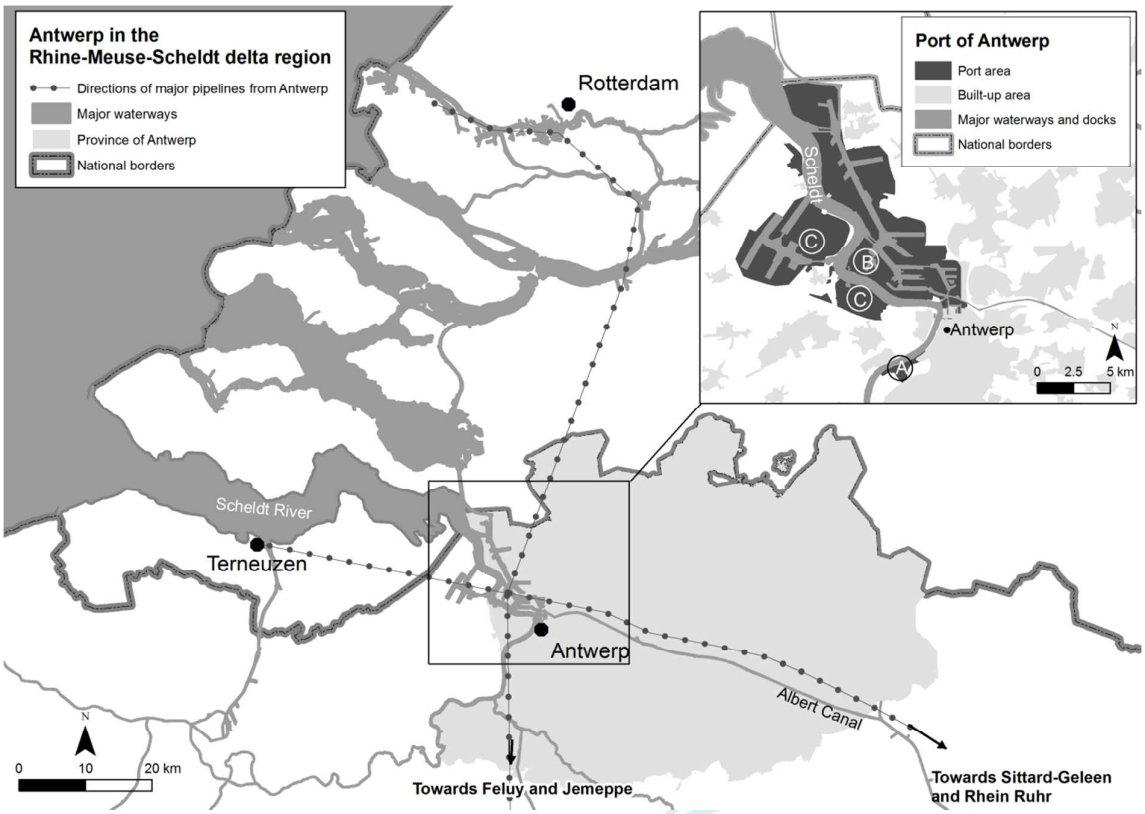

Figure 1. Antwerp in the Rhine-Meuse-Scheldt delta region.

Understanding evolution in the Antwerp chemical cluster: the role of regional development strategies

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Understanding evolution in the Antwerp chemical cluster: the role of regional development strategies

Research on regional economic development increasingly embraces more nuanced perspectives on the evolution of clusters, industries and agglomerations. The extent to which the emergence and decline of clusters can be directed with intentional regional development strategies is, however, a major point of discussion. The article links the cluster life cycle concept to regional development strategies in order to examine the trajectory of Europe's largest chemical complex in and around the Port of Antwerp (Belgium). This chemical cluster has matured and currently is in a state of sustainment. Although the cluster did not experience growth over the last decades in terms of new entrants, it did transform internally and maintained its importance as a production centre. Thus, whereas lock-in mechanisms hampered growth, they also prevented the cluster from going into a state of decline. We argue that while regional development strategies stimulated new emerging clusters in the Flemish region, vested interests in the port and associated lock-in mechanisms have resisted such developments in Antwerp. New growth trajectories based on the chemical cluster were therefore difficult to recreate in the Antwerp region.

Keywords: cluster life cycle; regional strategy; chemical industry; lock-in; Port of Antwerp; Flanders

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Introduction

~~The question why regional economies remain attractive and dynamic over time is an established topic in economic geography. Various scholars argue that regions, clusters and industries evolve according to a systematic life cycle pattern (Menzel & Fornahl, 2010; Potter & Watts, 2011). This suggests that clusters and industries, like the products they produce, display localised life cycles that eventually end in decline, stabilisation or renewal. With the rise of the evolutionary approach in economic geography, the importance of agglomeration effects is seen as depending on the particular development stage of a cluster or industry (Neffke, Henning, Boschma, Lundquist, & Olander, 2011). This body of work studies the emergence and decline of clusters and industries and examines why and how they change into new paths of economic development.~~

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~~The next section of this chapter will develop a conceptual framework based on insights from cluster life cycle theory, which is used to interpret lock-in and regional strategies for diversification. After a brief methodological section, the empirical section will apply a historical perspective in order to study the evolution of a chemical cluster based~~

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~~around the Port of Antwerp (Belgium). The life cycle of the chemical cluster in the port of Antwerp is discussed, describing lock-in mechanisms and their effects on the renewal of the chemical cluster and related industries. The final section reports on the role of regional economic strategies as a driver for renewal in the chemical industry.~~

The question why regional economies remain attractive and dynamic over time has been at the centre of attention in economic geography for decades. With the rise of the evolutionary approach in economic geography, novel ideas attempt to explain regional economic change in general and the formation of new industries and adaptation of existing industries in particular. To this purpose, concepts such as windows of locational opportunity that stress locational freedom in early stages of industrial development (Boschma & Van Der Knaap, 1999), path creation and emergence highlighting the role of existing industrial development paths (Martin & Sunley, 2006), and how the combination of (un)related activities might drive regional diversification and branching (Boschma, 2017) have been developed in the academic literature. Likewise, a body of work based around the 'life cycle' concept argues that industries, clusters and regions evolve according to a systematic pattern (Menzel & Fornahl, 2010; Potter & Watts, 2011). This research suggests that industries, clusters and regions like the products they produce, display localized life cycles that eventually end in decline or renewal. These ideas underline differential patterns of growth from region to region.

The rise of new research avenues coincided with the adoption of different policy approaches towards regional development (Vanthillo & Verhetsel, 2012). At the forefront is the example of the Third Industrial Revolution in Flanders that started well in the 1980s (Vanthillo & Verhetsel, 2012). Some time later the Basque Cluster Programme in Spain (Navarro, Valdaliso, Aranguren, & Magro, 2014), Peaks in the Delta in the Netherlands (Lagendijk & Boekema, 2008) and the Pôles de Compétitivité

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in France (Menu, 2012) illustrate the emergence of cluster approaches strongly intertwining industrial and regional policy. A set of newer policy approaches, such as place-based development (Barca, McCann, & Rodriguez-Pose, 2012), constructing regional advantage (Asheim, Boschma, & Cooke, 2011) and smart specialization (McCann & Ortega-Argilés, 2015) all have a particular objective in bringing together different but related activities within regions, instead of promoting particular sectors.

Drawing mainly upon life cycle theory, this article aims to link cluster change with regional development strategies, suggesting that specific policies are needed depending on the particular development stage of a cluster (Brenner & Schlump, 2011; Van Klink & De Langen, 2001). In this article, two dimensions are considered in particular. First, the potential role of regional strategies in providing conditions for the renewal of industrial clusters, and second, the extent to which an industry stimulates diversification in a particular stage of the life cycle. Many studies analysing regional evolution focus on old industrial regions, single-industry towns or peripheral regions (Hudson, 2005) or on dynamic growth regions such as Silicon Valley and Boston (Saxenian, 1994). Only few studies explicitly consider the relationship between mature clusters and industries in diversified regional economies and strategies envisioned by policy-makers (Coenen, Moodysson, & Martin, 2015; Njøs, Jakobsen, Wiig Aslesen, & Fløysand, 2016).

In our view, the recent paths of many chemical clusters in Europe offer interesting insights into the conditioning role of regional strategies on change and evolution. Since the 1950s, (petro)chemical clusters particularly emerged in port regions due to advances in research and development (R&D) and changing location preferences toward maritime locations. These clusters are industrial complexes as defined by Gordon & McCann (2000) and have guided the development of many regional

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economies around Europe in the last decades. Although most clusters have evolved to a mature or declining stage in their life cycle, they still represent a significant part of manufacturing activity in (inland) port regions and cities such as Antwerp, the Ruhr area, Teesside, Rotterdam, Tarragona, Ludwigshafen, Wilhelmshaven and Le Havre.

Many regional strategies, now and in the past, identified their local chemical industry as having a 'propulsive' power due to its considerable output linkages with other industries and therefore should be a focal point in the diversification of the existing industrial structure (Chapman, 2005). Undeniably, in the last decades new industries such as renewable energy, offshore and materials technology, recycling and storage have branched out of existing strengths related to the chemical industry. Big hopes have recently been set on the potential of the industry to further underpin a shift to a 'circular' or 'biobased' economy and the progress to 'green' and 'sustainable' chemistry. To explore these issues, the article analyses the evolution of the chemical cluster based around the port of Antwerp (Belgium), one of the world's largest and most diverse chemical complexes. The article seeks how in the past, for every stage of the cluster life cycle, the Antwerp chemical cluster has spurred local economic growth and examines the role of regional strategies in nurturing this growth. It further considers the potential of the mature cluster to diversify into new or related industries and once again enter into a growth trajectory. Of particular interest is the role of regional strategies aimed at stimulating this reorientation.

The next section of this article will develop a conceptual framework based on insights from cluster life cycle theory, which is used to interpret lock-in and regional strategies for diversification. After a brief methodological section, the empirical section will apply a historical perspective in order to study the evolution of a chemical cluster based around the Port of Antwerp (Belgium). The life cycle of the chemical cluster in

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the port of Antwerp is discussed, describing lock-in mechanisms and regional policies and their effects on the renewal of the chemical cluster and related industries. The final section reports on the role of current regional economic strategies as a driver for renewal in the chemical industry.

Conceptual framework: cluster life cycle, lock-in effects and regional strategies ~~for path creation and renewal~~

The cluster life cycle approach

The cluster life cycle theory provides a framework of the evolution of an industry cluster from its start to the decline stage (Menzel & Fornahl, 2010). It distinguishes among different cluster stages, starting with an emergence stage of fast growth, followed by a mature stage characterised by slow growth, and eventually a renewal or decline stage. Empirical research found a close interrelation between the life cycles of clusters and agglomerations (Neffke, Henning, Boschma, Lundquist, & Olander, 2011; Potter & Watts, 2011). Potter & Watts (2011) outline an evolutionary agglomeration theory which argues that the growth and decline of industry life cycles are important determinants of the success (and fall) of agglomerations and city-regions through time and geographical space, e.g. Sheffield and its metal industry.

The birth of a new industry in a region follows from a small group of firms that start to develop new knowledge, routines, technology, products or services that did not exist previously within a locality. At a certain moment, this industry cluster enters the growth stage of the life cycle and benefits from agglomeration effects caused by the rapid increase of new firm entries, start-ups and spin-offs. Firms still compete by pursuing a product differentiation strategy emphasised by research and development (R&D) or product innovation. When R&D investments steadily shift to process

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innovation focused on the efficiency of the production process, inter-industry spillovers become less likely and the cluster requires specialised, industry-specific machines, skills and knowledge (Chapman, 2005; Potter & Watts, 2011). This change fosters economies of scale and diffusion of successful routines in the region. A process that ultimately leads to specialiszation.

A number of changes have negative effects on the industry in general and the cluster in particular and cause a cluster to mature and sometimes even trigger the decline stage (Klepper, 1997; Van Klink & De Langen, 2001). First, the industry becomes very susceptible to exogenous shocks and unpredictable changes in their supplier or customer markets (Phelps & Ozawa, 2003). This can trigger a possible slowdown of the industry growth, for example because of local market saturation or product substitutions by disruptive innovation. Second, intensive price competition and the persistence of local negative externalities (i.e. labour cost, land rent, pollution, and congestion) lead to a further shakeout of firms. Firms that remain in the cluster after a shakeout adapt their routines and place emphasis on a variety of strategies that include geographic relocation, industry diversification, increasing plant size or business mergers and acquisitions (Fromhold-Eisebith, 2015). Third, firms will experience increasing returns from dispersion economies and will move across geographical space to, for example, lower-cost locations motivated by cost-saving strategies (Markusen, 1996). This stage often goes hand in hand with the emergence of branch plants and foreign direct investment by firms that spread out geographically and develop global production networks across continents. The cluster's success factors at this stage largely depend on the balance between a local and a global orientation (Bathelt, Malmberg, & Maskell, 2004; Coenen et al., 2015). It might be disintegrating because of the emigration and

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global reorientation of local and multinational firms, the decrease of inward foreign direct investments or too much focus on local technology.

Lock-in, renewal and path creation

It is in the mature stage of the cluster life cycle that a region can become locked in in a negative path-dependent trajectory (Grabher, 1993; Hassink, 2005). Marshall (1890) already described the risk of agglomeration and specializsation at the end of the 19th century as being '... a double-edged sword for economic development' (Potter & Watts, 2011, p. 445). There exist important dangers to bind the economic future of a region to a single dominant firm, cluster or industry (Hudson, 2005). This leads to a shared path dependence between region and cluster and results in a lock-in with as a consequence '... a loss of innovative momentum within regional agglomerations', as happened in many industrial regions around Europe (Chapman, 2005, p. 600). Path dependency and lock-in are two closely related concepts that are used to analyse differences in the ability of regional economies to reshape adjustment problems. Both concepts emphasise the importance of context and history in regional processes of industrial evolution.

Grabher (1993) identified lock-in as consisting of three mechanisms: functional, cognitive and political lock-in. Together these mechanisms create obstacles to regional change. Functional lock-in refers to hierarchical and stable firm relationships, particularly between large enterprises and small and medium-sized suppliers. This makes suppliers over-dependent on their customers and hinders them in monitoring new technology and switching to new markets in a structural crisis. Cognitive lock-in refers to a common rigid mind-set of a homogenous group, for example a number of incumbent firms, which hinders innovation and stimulates conservatism. Finally, political lock-in is associated with vested interests and is closely related to cognitive lock-in. It refers to a network of organisations and institutional actors aiming to

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preserve existing traditional industrial structures. The strength of shared relationships thus hinders change (Grabher, 1993; Greco & Di Fabbio, 2014; Hassink, 2005). These networks could therefore sometimes slow down industrial restructuring and indirectly hamper the development of endogenous potential and alternative directions for industrial development. On the other hand, a region with a high regional political status, active leadership and supportive national institutions that is able to formulate solutions for regional needs is a fundamental factor for regional renewal adaptability (Hu & Hassink, 2016). The three interrelated lock-ins manifest themselves at the regional level and are thus considered regional lock-ins, but the path is also influenced and affected by extra-regional factors like national and international institutions and regulations, lack of coordination and/or integration across policy domains at different spatial scales and global industrial transitions that transcend the regional level (Coenen et al., 2015; Trippl, Grillitsch, Isaksen, & Sinozic, 2015).

In contrast to traditional models, a more nuanced understanding of path dependence emerged arguing that path-dependent processes can be seen as both enabling and/or constraining regional economic adaption (Dawley, Pike, & Tomaney, 2010). The core of this argument follows from the idea that the creation of new regional development paths is always based on skills, knowledge and competences inherited from previous paths. In this sense different paths can be suggested for a region. Some mature industries and clusters opt for adjustment and adaptation or '... the extension of established trends, resulting in stagnation or gradual decline', while other industries choose renewal and adaptability or '... significant change of the existing trajectory of development, enabling the cluster to sustain its prosperity' (Chapman, MacKinnon, & Cumbers, 2004, p. 383). Based on these insights, Steen & Karlsen (2014) propose a

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continuum between regions that stay locked in declining trajectories without renewal dynamics and regions where new innovation paths are being created.

The degree of regional restructuring and the possibilities for regional evolution and renewal depend further on the relative strength of lock-in effects. In this paper, we argue that particularly industrial complex models (e.g. steel and chemicals), which in general have large firms with a closed membership based on stable and frequent trade relations, and long-term investments, are more prone to negative regional lock-ins, especially when the cluster is at a mature stage (Coenen et al., 2015; Gordon & McCann, 2000). We know that because of the characteristics of industrial complexes, firms may globally cluster in a very limited number of locations and that these clusters can persist over long periods of time. The resulting spatial pattern reflects traditional location factors based on the interplay of location-specific factor costs and transaction costs. Iammarino and McCann (2006, p. 1021) argue that: 'these location-specific sectors emerged initially as an industrial complex, and have remained so for over 50 years. As such, no real cluster-evolutionary path is discernible in this case'. A certain continuity and stability exists in the economic landscape and it might be tempting to describe this stability as evidence of lock-in (Martin, 2010). We, however, find in our case on the chemical cluster in Antwerp that although the localisation pattern may persist over a long period, it does not mean that the cluster has stopped evolving. The cluster may not experience growth in terms of new entrants, but rather evolves internally through new investments. More case-specific analysis is thus needed.

Regional strategies and de-locking mechanisms

Since the 1990s, cluster policies concentrate on the dynamics of change and on the endogenous creation of new paths (Hospers, 2005). Cluster-related organisations try to preserve a status-quo situation, forgoing an explicit focus on growth and are mostly

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involved in maintaining the cluster strengths and markets. Van Klink and De Langen (2001) argue that governments, together with firms, at the mature stage of the life cycle often should incentivise the development of new routines to form new combinations ensuring a certain degree of adaptation, renewal or transformation of the cluster (see also Brenner & Schlump, 2011). ~~Recently, concepts developed within evolutionary economic geography also started to influence regional innovation strategies and cluster policies (McCann & Ortega-Argilés, 2015). In the case of the European Union, most regional governments developed smart specialisation strategies (RIS3) under influence of the European Region Development Fund (ERDF) regulation in the last programming period 2014-2020.~~

Martin and Sunley (2006, p. 420) suggest a number of possible strategies for the reorientation of regional structures. These mechanisms help understand how local industry paths may be de-locked, disrupted and/or destroyed and how new paths emerge. They consist of:

- emergence of new endogenous technologies and industries from within the region;
- promotion of innovation and economic reconfiguration by heterogeneous economic agents;
- importing and embedding a new industry or technology from elsewhere;
- diversification to provide the basis of related new industries in the region;
- infusion of new technologies or introduction of new products and services.

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According to the RIS3-platform, regional strategies should try to diversify the existing industrial structure and upgrade value chains within related industries where competitive advantages exist and engage in new path creation by regional branching (European Commission, 2013). This mirrors the increasing interest of policy-makers in the second strategy (heterogeneity and diversity) and in some way the fourth strategy (diversification) to escape from a lock-in situation (Henning, Stam, & Wenting, 2013). The facilitation and use of de-locking strategies is important for a regional-economic structure because it affects the innovativeness and renewal opportunities of industries and clusters and the development of alternative paths. In the remainder of this paper, we apply the concepts developed above to the case of the Antwerp chemical cluster using a historical approach. More specifically, it is analysed how different lock-in effects and regional strategies throughout the cluster life cycle have affected cluster growth and path creation. It will also be discussed how the current generation of policy makers try to create new growth paths as well as the forces resisting this path creation.

Empirical analysis of the Antwerp chemical cluster

Case study approach

Empirical studies on the interaction between processes of economic development, regional growth factors and economic strategy are confronted with many limitations (Coenen et al., 2015; Elola, Valdaliso, López, & Aranguren, 2012; Trippl et al., 2015). No complete insight exists in the conditions under which regional strategies can renew the industrial structure in a region and generate a more resilient economic trajectory. A

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second relevant point is the limited understanding on the dynamics of industrial resilience and transformation, and the role that regional strategies take up in this process (Fromhold-Eisebith, 2015; Njøs et al., 2016). A clear view thus lacks on the conditioning role that regional strategies might play in the transformation and resilience of clusters and the stimulation of new industrial growth paths.

To address these issues, our case-study approach first contains a review of the life cycle of the chemical industry in and around the Port of Antwerp. We study location and industry-specific characteristics that help identify the phase of the life cycle throughout the history of the Antwerp chemical cluster. The second part assesses the presence of lock-in mechanisms. A third part, finally, discusses the conditioning role of regional development policies in Flanders on the chemical industry. Two dimensions are under particular scrutiny. First, the role of the old path industry in stimulating branching. Second, the role of regional- and sub-regional economic development strategies to provide conditions for renewal of mature industrial clusters and the extent to which new paths in the industry are created based on these strategies. The conceptual framework is used to interpret and explain strategies for diversification and related variety in the chemical industry in Flanders.

The data collection and analysis followed a process-based methodological framework (Yin, 2013). The process consisted out of four stages. The first part of the research included desk research in order to gather first insights and background information, develop additional interviews questions and build hypotheses. The second part included the conduction of interviews as primary data source for this article. We conducted 14 of in-depth interviews with a wide range of local authorities, firms and organisations. The interviews were done in two rounds. A first round of six interviews was completed in 2011. It provided an initial assessment of the chemical sector in

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Antwerp and the wider region of Flanders. Based on the results of these interviews main trends, inter-firm relations and cross-sectoral opportunities were discussed in a focus group in September 2012. The following part included additional research to verify the interview data. We further included a second round of eight interviews with public policy officials and cluster organisations concerning strategies for diversification that was completed in February and March 2016. The interview questions were semi-structured and covered five aspects: the presence of lock-in mechanisms, drivers of regional initiatives, de-locking strategies of the initiatives, the roles of regional strategies in affecting industrial dynamics and the role of the traditional chemical industry in new path creation. The fourth part consisted of converting the second round of interviews into the research. The gathered data was triangulated with a number of secondary data sources that included statistical data, government reports, policy documents and newspaper articles on contextual aspects of chemical industry and the case-study region. These strategies were followed to increase reliability and validity.

Findings: lock-in effects of a mature chemical cluster in the Port of Antwerp

In this section, we briefly discuss the historical development of the chemical cluster in Antwerp, from its genesis to its current state of maturity. Subsequently, this historical approach will be linked to the cluster life cycle theory. It will be argued that the Antwerp chemical cluster has matured and is in a state of sustainment. Various lock-in effects have emerged, which have prevented the cluster from going into a state of decline, but at the same time they hamper further growth. Finally, we discuss how government initiatives attempt to revitalise the cluster.

The history and evolution of the (petro)chemical industry in Antwerp

The genesis of the petrochemical industry in Antwerp was marked by the arrival of a

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ship carrying 40 barrels of American crude oil in 1861. It made Antwerp the first petroleum port on the European continent (Loyen, 2008; Van Cauwenbergh & Van Cauwenbergh, 1961). Almost immediately, dedicated facilities were built to accommodate to booming petroleum trade, storage and transhipment (see Figure 1, (a) on Port of Antwerp map). After WWII, the Belgian government together with Belgian chemical companies explored the possibilities of an integrated petrochemical complex for plastics production near the Port of Antwerp (Mommen, 2002). This initiative more or less initiated the switch from the embryonic stage to the emergence stage in the Antwerp (petro)chemical cluster life cycle. The development of this cluster was supported by external factors such as the favourable economic climate of the late 1940s in Belgium, advances in petrochemical R&D and changing location preferences of petrochemical companies toward maritime locations. From 1951 onwards, the foreign chemical companies British Petroleum, Philips Petroleum, ICI and Esso set up installations in a new petroleum port (see Figure 1, (b) on Port of Antwerp map) with funds made available by a public investment company, often in joint ventures with Belgian firms such as Petrofina and Solvay. Firms in the new petrochemical complex were attracted by the feedstock supply (i.e. naphtha and petroleum gasses) produced by refineries and facilities close by.

- INCLUDE Figure 1. Antwerp in the Rhine-Meuse-Scheldt delta region. AROUND HERE -

The mid-1950s, however, revealed several threats for the emerging petrochemical cluster in Antwerp. The supply of industrial grounds of the post-war extension proved to exceed demand very fast. At the same time, economic growth in Belgium slowed down considerably and was relatively low throughout the decade

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(Cassiers, 1994). Furthermore, increasing crude oil tanker sizes clashed with the limited draft depths of the Port of Antwerp. Despite these threats, the chemical cluster in Antwerp managed to evolve from an emerging into an explosive growth phase (Ron Boschma, 1999). The first important reason is the incentives provided by the port and municipal authorities, and the Belgian Government. These took the form of infrastructure investments in port extension and modernisation and the provision of various financial and tax incentives, including capital grants, state guarantees and equity financing, that remain important till today (EROV, 1966; Ryckewaert, 2010). Secondly, a positive functional lock-in effects specific to an industrial complex came into effect, e.g. companies had obtained favourable long-term port concessions or had acquired land in the port. These beneficial conditions were mostly unavailable in competing ports. The high sunk costs of installations also played a role in anchoring firms in the port. Finally, the already existing backward linkages could not easily be recreated anywhere else. As such, the cluster continued to grow in the 1960s and 1970s, attracting at least eleven mid- to large sized, mostly multinational, chemical companies. The construction of new pipelines and other multimodal infrastructure established inter-firm links to other sites in Belgium, The Netherlands and Germany (Van Der Auwera, Diels, & Van Til, 2013). This period also saw the emergence of the *naties*, traditional storage and transport providers for the port, as important service suppliers to the petrochemical firms in Antwerp. While their historical role in port activities was limited to simply providing links to the hinterland, they increasingly became involved in value added services that included providing storage, pumping stations and service buildings (Devos, 2002). In this sense, *naties* co-evolved together with their petrochemical partners in the cluster, further tying together logistics and chemical industries in the Antwerp region.

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Several port expansions were initiated during this period, e.g. the development of a new chemical cluster on the Left Bank of the river Scheldt (see Figure 1, (c) on Port of Antwerp map) (Dooms, Verbeke, & Haezendonck, 2013; EROV, 1966). The oil crises of the 1970s, however, halted further expansion plans within petrochemical industries, resulting in a considerable slowdown of port industrial development. It is from this moment on that we consider the cluster to be in the mature stage. Some new chemical companies did establish themselves on existing industrial port estates on the Left bank following the continuation of the existing beneficial fiscal regime. The cluster also attracted further investments in the 1980s and 1990s, mostly by companies already present in the port area, but the rapid growth stage was over.

The chemical industry as a whole is active at a global scale, but shows a strong tendency towards both economic and regional concentration (Bathelt, 1995). Research & development (R&D) and especially production is spatially concentrated in relatively few complexes around world. In the last decennia, the petrochemical complex in Antwerp has emerged as the second largest petrochemical cluster in the world, after Houston (USA) (Port of Antwerp, 2007). Although the chemical cluster in Antwerp is still regarded as being very competitive, industrial complexes in Jurong (Singapore), Jubail (Saudi Arabia) and Shanghai (China) are rapidly expanding and will overtake Antwerp as a petrochemical centre in the near future, especially in terms of volume.

Dimensions of cluster life cycle: a mature industrial complex

Using Van Klink and De Langen's (2001) six dimensions to assess cluster life cycle dynamics and matching them with our empirical findings, the chemical cluster in Antwerp seems to be in the mature stage for several reasons.

First, interactions in the chemical cluster value chain show proof of established economic relationships. The chemical industry in and around Antwerp is an example of

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an industrial complex model with integrated and developed complex value chains (Gordon & McCann, 2000). This complexity also resonates in the importance of reliable and stable relationships with suppliers and subcontractors, bringing along long-term contracts and obligations (Epicoco, 2016; Van Der Auwera et al., 2013). The strong input-output linkages limit the locational window for firms who want to invest in a particular chemical product or service to this industry.

Second, the stable roles of firms in the value chain have led to mature strategic relations. The cluster is in essence a closed club where membership is based on those willing to pay high entry and exit costs (Iammarino & McCann, 2006). The locational behaviour of firms depends on intentional strategic interactions and common planning decisions. This is evidenced by the small number of new entrants to the cluster since the 1970s. Furthermore, as observed by Bathelt (1995), the industry focus, since the collapse of the oil price in the mid-1980s, lies with efficiency gains in subcontracting relations in e.g. cargo-handling, storage, energy production and maintenance. The geographical range for an industrial complex model is typically local but can also spread across a regional level depending on transportation costs (Iammarino and McCann, 2006). New infrastructure lowered the price of feedstock transport making greenfield locations along the Albert Canal and some stand-alone sites in Belgium (e.g. Feluy, Jemeppe) attractive for petrochemical activities. The development of infrastructure within the port and between the different sites led to a regional-based co-evolving network of downstream operations and suppliers within the chemical industry (Cabus & Vanhaverbeke, 2003). However, some of these strategic relationships come under pressure as knowhow on advanced maintenance and engineering is increasingly moving towards the Middle East and Asia.

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Third, the demographic dynamics of the chemical cluster are similarly in a mature stage. Since the 1970s, large to medium-sized chemical companies only rarely entered the cluster, exceptions are for example Nippon Shokubai and Kuraray Eval. There is a stable presence of mainly international companies that occasionally change ownership, integrate, spin out or disinvest in various forms leading to frequent name changes. Important to note is the overall growth in the number and variability of chemical installations and products, marking an internal evolution of the cluster. Firms in Antwerp partly made the shift from bulk and commodity chemicals towards higher value added specialty chemicals with higher growth rates.

Fourth, in terms of success factors and innovation, the chemical cluster in Antwerp is considered to be in the mature phase for the following reasons: the nature of new investments made by firms, i.e. the focus on incremental process innovations, and the global competition in the chemical industry. Many multinational companies present in Antwerp developed a global production network as a consequence of strong competition with the Middle East and Asia in both the location of production facilities and the search for new growth in consumer markets, (Chapman, 2005; Dicken, 2011). This geographic spread and diversification of production facilities affected new investments negatively in Western Europe. However, the chemical cluster in Antwerp is performing well given the new investments by important focal firms in a time were refineries and chemical installations in stand-alone locations are closing down all over Europe (Loder, 2014). Some locations such as the Total and Esso refineries and the BASF *Verbund* installations are regarded as strategic sites for companies and as such are more likely to attract new investments than other sites. Most new investments in the Antwerp cluster are, however, focused on upgrading existing installations or on production expansion. But Antwerp is a world class production centre without a focus

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on R&D, in contrast to some German (Ruhr, Ludwigshafen) and Dutch (Limburg) regions where the presence of a large chemical industry or multinational headquarters leads to a high concentration of patents and fundamental R&D (Epicoco, 2016; Ponds & Van Oort, 2008). The need for optimised products and processes developed by large-scale corporate research, a high level of standardisation and certain and reliable connections to other firms in the cluster leads to a change-averse and protective sector with regard to innovation. This does not mean there is no R&D activity in Flanders, but it emphasizes incremental process innovation related to the high production volumes.

Fifth, the co-operative activities of firms, organisations and governments are clearly in a mature stage of the cluster life cycle. Over the years, the development of a large chemical cluster led to the provision of a wide range of industry specific services and institutions in the region. This includes education in tune with industry needs and the provision of shared infrastructure (e.g. marshalling yards and common pipelines). The sixth dimension, on the role of governments in stimulating the cluster, will be discussed in the next sections.

The chemical cluster as a locked-in industrial complex

We argued that the chemical cluster in Antwerp is an industrial complex in a mature life cycle. This makes the complex especially sensitive to negative regional lock-ins. Hassink (2010) identifies impact factors that contribute to the strength of regional lock-ins. Building upon his conceptualisation, two main sets of factors, namely economic-structural and political-institutional factors, are used to determine possible lock-in. In our opinion, there exists a certain degree of both negative and positive functional, cognitive and political lock-ins in the chemical cluster in the Antwerp region.

An indication for functional lock-in is the presence of a marked industrial mono-structure. According to the rough indicator set by Hassink (2010), this is certainly the

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case in Antwerp. The chemical industry plays an important role in the dynamism of the regional economy of the Antwerp (port) region and is of crucial importance for the broader Flemish and cross-border delta region (Vanelslander, Hintjens, Kuipers, & Van Der Horst, 2012). Employment is somewhat spatially dispersed across the province but strongly concentrated in specific poles of production, particularly in the Antwerp port area and along the Albert Canal. The chemical industry provides more than 30% of total industry manufacturing employment and 50% of industrial added value in the region. Furthermore, the sunk costs of capital-intensive chemical installations and public infrastructure contribute to a certain degree of functional lock-in. According to Hassink (2010) the industry's capital-intensive nature with high entry and exit barriers, and an above average company size within an oligopolistic market structure make it more prone to functional lock-in (Bathelt, 1995; Ketels, 2007).

The outlook for further development of the chemical cluster in Antwerp is then reasonably positive on the mid to long term. The persistence of strong agglomeration forces within an integrated industrial complex that stretches the wider region will most likely fuel new investments (as it has in the last decade) and keep operations at a certain stable level. The health of the chemical cluster or the firms at this moment is not a concern, as current investments in installations probably will generate positive economic yields for the coming decades.

The multinational firms present in the cluster have large internal R&D-budgets and continuously scan worldwide for new technology and process techniques. These innovations are implemented through investments in upgraded installations and keep the Antwerp production centre running at the lowest marginal cost and the highest reliability possible. The cluster has thus an outward orientation in terms of economic relationships. It makes the cluster less prone to negative functional lock-ins. But another

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indicator for lock-in includes the performance of the regional innovation system. The observation that there are no direct linkages to regional research and development through the regional innovation system is worrying from a regional development perspective, especially with regard to possible spillovers to other industries.

Cognitive and political lock-in is impacted by a second set of factors. The Port of Antwerp and its constituting industries are seen as one of the economic engines of Belgium (Van Nieuwenhove, 2015). Since the expansion stage in the 1950s, the chemical industry in Flanders enjoys widespread political support at all levels of government, ranging from the local to the provincial, regional and federal level. In the region, a strong focus exists on accommodating the basic cluster needs, including specific multimodal infrastructure, a tailored education system, facilities and the subsidisation of innovation projects. These do not just pertain to the main players in the cluster, but also to supplying industries.

Chemical industry in Flanders: policy as driver for diversification, adjustment, and renewal?

Across the history of the chemical industry in Antwerp, national, regional and local policies have been put in place to support the chemical industry in the port of Antwerp. In contemporary Flanders, the ~~four~~ de-locking mechanisms provided by Martin and Sunley (2006), are combined to try and create new paths or diversify the chemical industry.

The new Flemish cluster policy is an example of how the Flemish Government tries to marshal technological development (Vlaamse Regering, 2015). Policy makers have selected a limited number of internationally leading and large-scale industries. This is a rather traditional regional cluster policy, promoting 'national champions' from an established set of industries (see e.g. Njøs et al., 2016). The sector organisations

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governing the selected priority clusters will subsequently receive the necessary funding and earmarked funds from the Flemish innovation budget for the next ten years. Flanders Innovation Hub for Sustainable Chemistry (FISCH), now rebranded as Catalisti, was one of the organisations asked to apply for this spearhead cluster status. It is a member organisation founded in 2010, supported by the Flemish Government, chemical sector organisation Essenscia, Flemish universities and private companies, with the goal of developing demand-driven innovation activities in the field of sustainable chemistry with direct use-value for the companies part of the consortium.

Another approach is the search for new value chains with related and unrelated sectors such as the pharmaceutical, building and textile industry based on ideas like cross-fertilisation, related variety and diversification. It is an example of finding synergies between heterogeneous economic agents. The Flemish government financially supports and facilitates policy experimentation and innovation initiatives by research institutes and network organisations related to the development of new value chains in the broad chemical industry in Antwerp and its surrounding regions. Other initiatives include the active search for co-siting possibilities with companies that could 'fill the gaps in the complex' and/or bring in new expertise in energy provision, maintenance or new products.

A third approach is upgrading the existing industry by looking into other feedstocks (e.g. bio-based) than traditional carbon-based feedstocks, i.e. diversifying the existing industry. Bio-based initiatives developed hesitantly in Flanders for several reasons. Hintjens et al. (2015), in a recent study on the cross-border delta region, found that Antwerp initially did not play an important role in bio-based development. There are, however, signs that the attitude towards bio-based, also in the Antwerp cluster, is changing. Where some years ago the majority of the chemical industry would have

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discarded bio-based developments due to the lack of standardised products, small volumes or the destructive character on some chemical products, cluster firms and organisations have changed their point of view. The circular economy, (i.e. waste-to-chemical) is seen by various actors as a very important emerging field where Flanders could be an innovation leader. The Antwerp Port Authority recently stressed the importance of the circular economy by designating a large vacant concession for it (Port of Antwerp, 2016). Furthermore BASF recently announced a joint-venture with the Dutch Shell spin-off Avantium to produce bio-based packaging on its site in Antwerp (Verbraeken, 2016). However, the core of bio-based research, development and economic activity in the region lies around the Port of Ghent (Hintjens et al., 2015). The bio-based cluster in Ghent received financial and legislative support stimulating innovative behaviour, which are characteristics of an emerging cluster. This is different in Antwerp where federal, Flemish and municipal tax incentives, the concession policy of the Port Authority and agglomeration benefits related to the production centre attract companies toward the region. These are clear characteristics of a mature cluster. The instruments that are used are almost identical to those in the 1950s and 1960s. The broad chemical cluster is in this sense facilitated over other industries, reflecting cognitive and political lock-ins.

A last approach reflects the focus on internationalisation and, more specifically on the broader international Antwerp-Rotterdam-Rhine-Ruhr-Area (ARRRA) cluster (Ketels, 2007). This approach supplements the three other mechanisms by bringing together partners and funding streams for innovation projects, conduct common lobby activities to international organisations such as the European Commission and perform common acquisition activities abroad. Moreover, the extra-regional component will become more important in new cluster strategies. In September 2017, Flanders, North

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Rhine-Westphalia and the Netherlands presented a common strategy on the chemical industry. And the Flemish Dutch Delta (VN Delta) developed a strategy to build a cross-border world-class cluster in sustainable chemistry and bio-based economy. Where the former initiatives reflect the vested interest of the traditional chemical industries, the latter tries to incorporate both the interests of the main ports and chemical clusters with bottom-up bio-based initiatives scattered around the delta region.

Discussion and conclusion

In this paper, we analysed the Antwerp chemical cluster by assessing its position on the cluster life cycle, next we evaluated the dimensions of the cluster life-cycle, considering the state of lock-in and finally gave an overview of regional strategies. The cluster in Antwerp is a mature production centre that crucially depends on agglomeration effects and transaction costs. These characteristics make it more prone to negative lock-in effects. We demonstrate the presence of functional and cognitive lock-in in the Antwerp region. The conceptual framework helps nuancing our understanding of lock-in, arguing they do not have to be totally negative. This influenced our rather positive outlook for the Port of Antwerp chemical cluster on the mid to long term. The prolonged mature life cycle stage of the cluster started with a focus on subcontracting relationships in the 1970s, the surge of specialty chemicals installations in the 1980s and 1990s and will now be further extended with bio-based and waste-to-chemical products. The successful internal evolution of the cluster is based on the continuous upgrading of existing facilities, the presence of a specialised workforce with strong innovation capacities in ready to use process techniques and the transplantation of new product opportunities by extra-regional scanning of multinational companies already present in the cluster. The Antwerp region never really succeeded in attracting large corporate research facilities, making fundamental R&D unlikely. The cluster members implant mainly process-based

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and minor product-based innovations. The cluster thus sustains itself, but the conservatism of cluster actors also means that new growth paths based on fundamental R&D remain unexplored.

From a public policy point of view, the dominant presence of the traditional chemical industry in several regional strategies has had a constraining effect on innovation and investments in sustainable chemistry and bio-based developments in Flanders. Additionally, previous research has shown that innovation opportunities are rarer in the mature stage of the industry life cycle because inter-industry spillovers become less likely with the focus on process innovation (Neffke et al., 2011). Our research analysed the connections between regional strategies in setting the conditions for cluster change: it reflects the importance of classic regional policy mechanisms i.e. tax incentives, partnering with multinational companies and site allocations. This confirms the proven recipes for success from 1950s and 1960s. The Antwerp case is thus seen as path-extending the traditional chemical cluster.

Policy makers, however, do show some form of experimentation, trying to create new value chains in co-operation with sector organisations. Corporate and regional strategies recently shifted from transplantation of technology from abroad towards triggering new developments of endogenous capacity through platform development based on the existing local knowledge base and capabilities. It is too early to assess the results of these developments and whether this will eventually lead to fundamental endogenous R&D, remains to be seen. Although some pressure on the stable roles of cluster firms in the Antwerp chemical cluster exists through new relationships with bio-based and engineering companies, there is no evidence of a possible reconfiguration of strategic relations.

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The strong focus on the chemical cluster created in various ways a considerable expertise of the regional work force in terms of practices, skills and knowledge and developed industrial capabilities in the chemical cluster, supplying industries and specialised services. Furthermore, there exists a dominant (port-based) industrial production structure in the region and a ~~physical~~ spatial and institutional structure has developed to sustain these sectors. This may all be beneficial to cluster sustainment, but it can also be argued that the concentration and build-up of public and private investments, infrastructure, practices and skills related to chemical cluster might become a constraint for new path development (Chapman, 2005; Grabher, 1993). Our main concern lies in the interdependence with co-evolving industries that are fundamentally embedded in sustaining the chemical activity in Flanders. The opportunity cost of deployed resources, both public and private, in the chemical cluster and related industries cannot be used for supporting new development of technologies, industries or human capital. This focus lowers the capacity of the regional economy to adapt to wider processes of economic change, especially in our case where many of these processes are dependent on extra-regional relations and global processes.

We conclude that it becomes hard to recreate new growth trajectories related to the chemical industry in the Antwerp region through diversification in the region. Regional strategies can only to a certain degree condition new growth paths in a mature industrial complex. In the future we see both sustainable chemistry and bio-based development being absorbed in the Antwerp chemical cluster. Not that innovation capacity currently located elsewhere will move into the cluster, but rather that large scale production plants will be set up based on new innovative products and processes by existing actors.

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