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ABSTRACT: The breaking with regime logics is one of the key points to enable a socio-technical transition. Understanding how, and under what conditions, this may happen is thus an important task for transition studies. Recent research on regime structures and rationalities has shown that they may be less geographically bound than previously assumed. Regimes may instead be replicated and reinforced globally through networks of multi-national companies (MNCs), international interest organizations, and other actor groups. This paper studies the dynamics of a sustainability initiative of Swedish subsidiaries of global MNCs in the chemical industry as an example of how global regimes are locally embedded, although globally institutionalized globally. Local sustainability transition initiatives must thus challenge not only local institutions and rationalities but also global ones. The chemical industry is today dominated by a small number of large MNCs, which have also been the ones developing technologies and processes over many decades. The stability in this sector has been remarkably high and through global markets for technologies and products a global regime focused on the efficient use of petroleum resources has been developed. Four dimensions of dynamics that bridge the local and the global are identified; institutional contradictions, internal competition, inadequate networks, and inconsistent aims and expectations. Each of these dimensions contributes to shaping pathways for local transitions in systems that are dependent on developments outside the local and national context.

KEYWORDS: socio-technical regime; institutional change; industrial development; chemical industry

1 Introduction

It is widely agreed that there is a great need to transform contemporary economies towards more sustainable modes of production and consumption to not risk undermining the carrying capacity of the planet. Although large and increasing efforts are being invested into research, development, and innovation for more sustainable production technologies, these meet with significant barriers of a socio-political and institutional nature. Research in the area of sustainability transitions has made substantial contributions to understanding the complex dynamics of transforming economies and societies (Grin et al., 2010, Markard et al., 2012). Taking a socio-technical and systemic perspective, studies have pointed to the many ways in which institutions and technologies have historically co-evolved into "configurations that work" (Rip and Kemp, 1998) in industries such as energy, water, and transportation. Scholars have developed theoretical frameworks that conceptualize the dynamics of socio-technical systems, among other things focusing on the reasons for the substantial path-dependency encountered in current industries, as well as potential sources for innovation, change, and renewal (Coenen and Díaz López, 2010).

A central line of research has studied the role of technological niches, i.e. protected spaces for path-breaking innovations, for the development and diffusion of new technologies and practices (Hoogma et al., 2002, Smith and Raven, 2012). Oftentimes niches have been described as fighting against rigid and hegemonic socio-technical regimes, which represent the dominant "rules of the game" that guide the behaviour of actors and render systems path-dependent (Geels, 2004). Recent contributions on the nature of regimes have described the regime as a cultural-cognitive, institutional rationality that is diffused throughout a system and provides actors with sets of routines and legitimate ways of acting (Fuenfschilling and Truffer, 2014, Smink et al., 2015, Wirth et al., 2013). Although these institutional rationalities differ between countries with divergent traditions, standards, and legal systems, they are also surprisingly similar across contexts (Fuenfschilling and Binz, 2018). Organizations, industries, and markets are increasingly international and form global networks in which ideas, practices, and routines are diffused and coordinated. This globalization has been described in terms of global production networks (Coe et al., 2008), global value chains (Gereffi et al., 2005), and recently also global innovation systems (Binz and Truffer, 2017). Innovation and transition processes are thus bound to play out in contexts with significant influence from these international networks (Binz et al., 2014, Sengers and Raven, 2015, Truffer and Coenen, 2012). Simultaneously, scholars have shown that industry emergence is oftentimes distinctly local. Local preconditions, proximity effects, and local actions are important for the development, support, and alignment of new "configurations that work" (Asheim and Coenen, 2006, Binz et al., 2015, Dewald and Truffer, 2011). Investigating the dynamics between the local and the global, i.e. shedding light on the specific geography of transitions, is therefore crucial to understand how, where, and why innovations come about, how transitions unfold, and on what level policy interventions matter (Coenen et al., 2012, Truffer et al., 2015).

In this paper, we aim to illuminate a particular aspect of such multi-scalar dynamics, namely the interrelations between global regimes and local sustainability initiatives. We analyze and compare the influence of local preconditions and the global regime on the process ofdeveloping and institutionalizing sustainable solutions. We illustrate various re-enforcing and hindering factors stemming from the multi-scalar structure in an industry. Our empirical analysis is conducted in the chemical sector. We study the dynamics between the global regime of the chemical industry and a local group of chemical firms in

Stenungsund, Sweden, that have collaborated to establish a shared vision, engage in innovation for a sustainable chemical industry, and break with the fossil-based global regime.

The paper is structured as follows: in section 2 we outline some of the core theoretical assumptions about the geography of transitions; in section 3 we describe our methodological approach and introduce the chosen case and in section 4 and 5 we present and discuss the results of our analysis. We conclude with some thoughts on future research avenues in the field of geography of sustainability transitions.

2 The geography of sustainability transitions

Research on sustainability transitions has recently seen an increase in studies that deal with the spatial particularities of transition dynamics (Coenen et al., 2012, Truffer et al., 2015). The central argument is that without an explicit treatment of space, current theoretical frameworks such as the technological innovation system (TIS) or multi-level perspective (MLP) will lose their explanatory value. A main reason for this is that important structural preconditions for innovation and change, e.g. institutions, actors, or networks, as well as key processes like market formation or knowledge generation all have distinct industrial as well as territorial characteristics that shape where and how transformative change unfolds.

Dominant theoretical frameworks in transition studies like TIS or MLP generally assume that socio-technical systems form around specific technologies or sectors, thereby prioritizing industrial system boundaries when it comes to the delineation of relevant actors, networks or institutions (Coenen and Díaz López, 2010). Studies have for instance analyzed innovation systems for renewable energy technologies (Jacobsson et al., 2004, Negro, 2007) and followed transformations in dominant regimes in the car, pulp and paper, and coal industries (Karltorp and Sandén, 2012, Penna and Geels, 2012, Turnheim and Geels, 2013). The sectoral focus can partly be interpreted as a reaction towards the originally dominant focus on the nation-state in innovation studies. Frameworks with a national perspective, such as national innovation systems or varieties of capitalism, were substantially criticized for neglecting relevant dynamics of innovation processes happening on other geographical scales (Carlsson and Stankiewicz, 1991). However, empirical studies using TIS and MLP commonly limit their analysis to specific countries, e.g. studying the wind industry in Denmark or photovoltaics in Germany. This nation-state bias was subsequently criticized by scholars advocating a more explicit treatment of space as innovation and change are unequally distributed (Coenen et al., 2012, Hansen and Coenen, 2015). The questions arise why particular activities and developments occur in some places but not others, as well as how developments in different places relate to one another. It has become clear that activities and structures on different geographical scales influence innovation and transition dynamics. Two specific geographical scales are particularily important: the global and the local (Truffer, 2016).

First, a brief elaboration on the global dimension. Transition research is interested in how established sectors overhaul their dominant socio-technical configuration in addition to how new socio-technical configurations emerge and diffuse. As well current socio-technical regimes as emerging niches and innovation systems are inherently global phenomena. (Fuenfschilling and Binz, 2018) show that regimes in many industries are global, a fact that has important consequences for the stability and potential for transformation of these regimes. A central argument concerns the role of institutions and networks for transition dynamics. Actors and practices are commonly assumed to be embedded within a broader institutional context that guides behavior through a certain set of rules and routines. It is thus important to consider where such a relevant institutional context emerges. Intuitively, national borders are a natural starting point, since many regulations as well as cultural understandings and expectations are often state specific. However, research in institutional theory has shown that many relevant institutional structures have global validity and are constructed, maintained, and modified by international actors (Boli and Thomas, 1997, J. W. Meyer et al., 1997). Labor laws are streamlined by the International Labor Organization (ILO), professional standards are created by multi-national consultancies and certified by the International Standardization Organization (ISO), routines and certified procedures are developed by international trade associations, values like sustainability and human rights are put into practice and defended by international non-governmental organizations, and supranational organizations such as agencies of the United Nations partake in establishing rules and protocols with global reach. Additionally, relevant institutional contexts are often highly industry specific, formed around organizational fields, which include all relevant actors that contribute to a "recognized area of institutional life" such as suppliers, consumers, regulators, and competitors (DiMaggio and Powell, 1983).

Furthermore, studies on global production networks and value chains have demonstrated that economic activity has increasingly become dispersed to multiple geographical locations and that industries are more often than not organized at an international scale, e.g. in large multi-national corporations (MNCs) and their subsidiaries (Gereffi, 1999, Yeung and Coe, 2015). Actors are embedded within institutional settings that exceed national boundaries and that are constantly reproduced and transformed by international actors and their networks. (Fuenfschilling and Binz, 2018) conclude that socio-technical regimes are not just defined by local and national conditions, as often done in transition case studies, but that the dominant rules of the game are indeed global. A global regime can thus be defined as the "dominant institutional rationality in a socio-technical system, which depicts a structural pattern between actors, institutions and technologies that has reached validity beyond specific territorial contexts, and which is diffused through internationalized networks" (Fuenfschilling and Binz, 2018).

In addition, it has been shown that also emerging technological niches have global dimensions. Niche development has often been considered a local phenomenon, ignoring the increasingly internationalized nature of modern societies that makes the emergence and diffusion of innovations a global process. (Sengers and Raven, 2015) analyzed the diffusion of Bus Rapid Transit (BRT) systems to over hundred cities in the global south, showing that many local developments are actually globally connected, often through a range of international experts travelling between cities. In a similar vein (Binz et al., 2014) show that knowledge creation is transnational process, although not evenly distributed. Using social network analysis they show that collaborations around membrane bioreactor technology development include researchers and firms from several continents. Recently a more comprehensive conceptual framework has been developed, which allows for the study of innovation dynamics in transnational contexts using the notion of "global innovation systems" (Binz and Truffer, 2017). Transition dynamics cannot be understood by studying developments on just one geographical scale as "the spatial configuration of innovation systems is getting more complex, spanning actor networks and institutional contexts from various places and across spatial scales" (Binz and Truffer, 2017)..

While these contributions highlight the transnational dimensions of innovation and change, they also often emphasize the importance of the local, albeit in different ways. In their review of studies on the geography of transitions (Hansen and Coenen, 2015) categorized the most important insights regarding the role of different spatial scales for sustainability transitions. The analysis revealed the great relevance of the local scale in terms of urban/regional visions and policies, informal local institutions, local natural resource endowments, local technological and industrial specialization, localized knowledge spillovers, as well as local consumers and market formation. Two distinct but interrelated characteristics of the local stand out: its role for place specific institutions and agency..

Contributions in evolutionary economic geography have long pointed to the importance of geographical proximity and so called agglomeration economies for innovation and industry dynamics. These factors lead to a certain localized arrangement of capabilities, knowledge, routines, and institutions (Asheim and Coenen, 2005, Coenen et al., 2010, Cooke et al., 1997, Storper, 1997). Studies often emphasize the role of local cultures, networks, policies, visions, and knowledge bases for industrial dynamics. Similarly, local preconditions and local actions have also been identified as important explanatory factors for transition dynamics. One example is the creation of the photovoltaic market in Germany, which is often explained with the introduction of the feed-in tariff, a specific policy instrument for renewable energy. However, a single top-down policy instrument falls short in explaining the overall success, as various less successful introductions of feed-in tariffs in other countries and for other technologies have shown (Jenner et al., 2013).. (Dewald and Truffer, 2011) show how local communities in a few German states started transforming their energy systems in reaction to the nuclear catastrophe in Chernobyl. Those civic initiatives were slowly building up new socio-technical configurations by continuously aligning technological specificities and local institutional environments. The authors conclude that these local processes were essential for the subsequent roll-out of the national feed-in tariff that accelerated the development.

The importance of local action and specific local preconditions for the development of new, potentially more sustainable socio-technical configurations has also been demonstrated in other industries and places. (Garud and Karnøe, 2003), for instance, compare the emergence of wind turbines in the United States and Denmark, concluding that the engagement of local farmers in Denmark was particularly decisive for the success of the Danish wind industry. Similarly, (Binz et al., 2016) show that a deliberate effort of local embedding was crucial for successfully creating legitimacy for direct potable reuse of wastewater in Orange County, California. Attempts to introduce this rather controversial technology in other counties often failed because of missing local support or even organized resistance.

Acknowledging the importance of not only national, but also global and local developments has put the necessity of a multi-scalar perspective on transition dynamics center stage (Fuenfschilling and Binz, 2018, Hansen and Coenen, 2015, Murphy, 2015, Truffer et al., 2015). Scholars call for a more in-depth study of the dynamics between the multiple "concrete geographical spaces" and "abstract economic spaces" (Grillitsch et al., 2017), i.e. of the interrelation between various territorial and industrial structures and activities. In this paper, we address this call by studying multi-scalar transition dynamics within the chemical industry. More precisely, we investigate the interdependencies between the global regime of the sector and a local sustainability initiative in Stenungsund, Sweden. We show how and why the sustainability initiative emerged in this particular place, how it tried to break with global regime structures and how the global regime impacted its success. In so doing, we discuss the implication of multi-scalar dynamics for a transition towards sustainability in the industry. The next section introduces the case and describes our methodology.

3 Case and method

Multi-scalar transition dynamics can be identified and observed in different parts of the economy, but few provide better examples than the energy intensive manufacturing process industries. Despite their key role in many value chains as manufacturers of important materials and products, they have largely been overlooked in international climate policy (Åhman and Nilsson, 2015, Åhman et al., 2017) as well as the literature on sustainability transitions (Wesseling et al., 2017). These industries share important characteristics in terms of their structures, markets, and innovation strategies: long investment cycles, focus on incremental process improvement, large scale of operations and associated large investment costs have been identified as significant structural barriers for transformative change (Wesseling et al., 2017). An exemplar of these factors is the chemical industry. The sector is highly globalized and dominated by large MNCs, many of which have had a leading position in the sector for more than a century – e.g. BASF, DowDuPont, and Bayer – and have developed concurrently with the "carbon lock-in" (Unruh, 2000) in which the sector finds itself. The sector has throughout its existence been tightly connected to, and completely dependent on, the use of fossil resources, both for its large energy demand and as feedstock for its products. In the 19th century it used coal, but during the 20th century it underwent a transition towards petroleum and natural gas - 92% of chemical products are currently reported to be produced from these feedstocks (Bennett, 2012, Bennett and Pearson, 2009).

The chemical industry can thus be assumed to operate under a highly stable, global, and rather unsustainable socio-technical regime. The increasing concern for sustainability since the 1980s has however led to both international and local initiatives for a more sustainable industry. In this paper, we will investigate the dynamics between the global regime of the chemical industry and a specific collaborative sustainability initiative started by a group of five MNC subsidiaries in Stenungsund, Sweden, called Sustainable Chemistry 2030. The empirical analysis contains three parts: 1) The identification of the global socio-technical regime; 2) the identification of the local preconditions and the local initiative; 3) the analysis of the dynamics between the global and local structures and developments.

In order to address all three aspects, our analysis triangulates a variety of qualitative data from different sources. For the reconstruction of global and local preconditions and activities, we heavily draw on secondary data, such as previous research on the chemical industry and its sectoral characteristics, as well as material and documents produced and published by industry associations and important global actors in the industry, e.g. annual reports, statistics, public statements, presentations, press releases, and company websites. Interviews are used to get more in-depth knowledge on the actual process of the emergence of the local sustainability initiative. Semi-structured interviews were conducted with 12 persons who were actively involved in the local initiative and its associated projects, providing the primary data source for information regarding the local Swedish initiative. Most interviews were conducted in face-to-face meetings, but for scheduling reasons two were held over phone and two were group sessions. The use of these different data sources allowed for triangulation and possibilities to check the validity of claims made.

4 Findings

4.1 The global socio-technical regime of the chemical industry – origins and characteristics

The chemical industry emerged in Europe during the first half of the 19th century following the first industrial revolution, which increased the demand for dyestuffs in the textile industry (Aftalion, 2001). The scientific search for new dyestuffs rapidly established synthetic ones produced from coal derivatives as the way forward and institutionalized the science-based innovation pattern that has marked the industry (Pavitt, 1984, Walsh, 1984). It also created strong links between the chemical industry and the exploitation of the new energy resource coal, initiating the 'special relationship' between the chemical and energy industries that still remains (Bennett, 2007). This relationship is evident both in terms of organizational and material structures, such as the integration of fuels and chemicals production within MNCs, e.g. ExxonMobil and BP, and the flows of feedstocks and products between petroleum refineries and chemical production plants, e.g. in large petrochemical clusters such as Rotterdam (NL) and Baton Rouge (USA). The relationship between the chemical and energy sectors is also institutionalized in the knowledge base of chemical engineering, which has become the foundation for operations in petroleum and natural gas processing as well as chemical production since its emergence in the early 20th century (Rosenberg, 2000). With the take-off for polymers and synthetic materials in the middle of the 20th century, the sector was transformed from a regionally based industry almost completely based on the use of coal towards a global industry closely linked to petroleum (Bennett and Pearson, 2009).

The production of basic chemicals, some of which are produced in quantities of more than 100 million tons per year, e.g. sulfuric acid, ammonia and ethylene, relies heavily on economies of scale.As the products are on a molecular level identical, developing product innovations that give a market advantage is difficult. The market is thus dominated by price competition and firms engage in cost leadership strategies which guide their innovation initiatives (Albach et al., 1996, Ren, 2009). Product innovation is largely about finding new applications for existing products that are already produced in the scale of millions of tons per annum, or producing completely new products which have some advantage to existing ones, e.g. being less toxic. As basic chemicals are to a large extent traded within the industry for further conversion to more complex products, product innovation is however limited by strict requirements of downstream processes. The dominating form of research, development, and innovation (RDI) thus relates to process improvement, i.e. increasing productivity or decreasing costs of production through improved energy efficiency or higher conversion rates (Cesaroni et al., 2004). RDI leading to full commercialization requires large industrial laboratories, highly skilled workers and years of testing – factors that all contribute to high costs for RDI. It has been shown that energy cost saving is one of the main drivers for process innovation in the petrochemical industry (Ren, 2009), which constitutes a large and important part of the whole sector. The process innovation efforts resulted in a 27.1 % decrease in total fuel and power consumption in the European chemical industry (similar to EU total industry decrease which was 26.8 %), and a decrease in energy intensity of chemical production of 54.5 % from 1990 to 2009 (cf. EU total industry decrease was 35.8 %) (Cefic, 2012).

The large and old chemical firms are the most important actors in the chemical sector, but also the specialized engineering firms (SEF) which emerged in the second half of the 20th century have been identified as playing an important role for innovation in the chemical industry (Arora et al., 2001, Freeman, 1968). These are firms, many of them also global MNCs, which do not themselves engage in the production of chemicals but are specialized in RDI of chemical process technologies, e.g. Haldor Topsoe, Stamicarbon, and Jacobs Engineering. They engage in activities to improve existing and develop new processes which are then licensed to the firms producing the chemicals. Many of the large chemical firms compete with the SEFs to develop production processes, especially for the important basic chemicals. As several process technologies have been developed for the production of most basic chemicals, the knowledge that competitors can license a process from different sources has forced the large chemical firms to license their own technology to their competitors. This has created a special structure in the market for technology in the chemical industry where many firms use and depend on their competitors' technologies and related RDI, which leads to a rapid diffusion of key technologies across the globe (Arora, 1997, Arora and Fosfuri, 2000).

The permanence of the actor structure, the dominance of a small number of global actors and their long-term grip on the sector, the science-based and cumulative pattern of innovation - mainly focused on incremental process improvements - and the global markets for both technologies and products clearly favor large, multi-national incumbents and create significant barriers for new, entrepreneurial firms to enter. This is further supported by analyses showing that patents tend to be granted to the same few, large companies over decades (Breschi et al., 2000). Stability is thus a keyword when describing the structure of the chemical industry.

4.2 Global developments in the age of sustainability transitions

Once the focal point of critique from the environmental movement (e.g. in Rachel Carson's Silent Spring, 1962), the discourse on environmental issues influenced and changed the chemical industry during subsequent decades (Hoffman, 1999) (Díaz López and Montalvo, 2015). Regulating global industries is well-known to be a difficult task as differences in regulation between countries can be exploited by global MNCs.The chemical industry has tended to reject both the existence of many environmental problems and the necessity for regulation to come to terms with the problems (Johnson, 2012). The sector has however been the target for global environmental regulation efforts aiming to reduce the environmental impact of specific chemicals: the Montreal protocol (1987) aimed at reducing the depletion of the ozone layer resulting from the emission of chlorofluorocarbons; the Stockholm convention (2001) aimed at restricting the production and use of persistent organic pollutants such as DDT; the Minamata convention (2013) aimed at reducing anthropogenic emissions of mercury.

Responding to growing concern about the environmental impact of the sector and its safety standards after the accidents in Seveso and Bhopal, the self-regulation program Responsible Care was launched by the Canadian Chemical Producers Association in 1985 (Gunningham, 1995, Rees, 1997). The program was later adopted by other trade associations around the globe and is today stewarded by the International Council of Chemical Associations (ICCA). It has become the globally institutionalized standard for safety and environmental performance; the global charter is signed by 90% of the world's largest chemical producers. The voluntary program has however been criticized for being ineffective in regulating environmental performance, as ambitious industry self-regulation is difficult to maintain (King and Lenox, 2000). The framing of environmental sustainability in the sector has to a large degree focused on the safety and energy efficiency in the production of chemicals, as well as on the role of advanced chemicals and materials in enabling renewable energy. The fundamentally unsustainable dependency on fossil resources for the chemical products, however, has largely been neglected. Instead, the industry prides itself with contributing to sustainable goals and the development of environmentally friendly applications in other sectors:

> *"Nearly all renewable energy sources and technologies – wind, solar, natural gas and new vehicle technologies – depend on innovations in chemistry to become more efficient, affordable and scalable. … Chemistry makes possible the new technologies and materials needed for sustainable construction and urban mobility, including new insulation, adhesives, sealants and lightweight materials used by both the construction and transport sectors." (ICCA website)*

> *"A comprehensive energy strategy must harness all viable energy sources, non-renewable and renewable, including recovering energy from waste. Policies should also ensure reliable access to energy raw material or feedstock, recognizing their vital role for the chemical industry, including their use in the manufacture of energy-saving materials and products" (ICCA leaflet "Principles for an efficient energy and feedstock policy")*

The possibility for the chemical industry to be part of the transition to a bioeconomy gained traction following the publication of high-profile reports from the US DOE which identified new platform chemicals that could be derived from renewable resources (Bozell and Petersen, 2010). Actors in the industry started researching new technologies and production processes for this purpose. Biorefineries, for instance, could make use of the fundamental idea of a petroleum refinery to convert complex raw materials into a range of different intermediary products but using biobased feedstocks (Bauer et al., 2017). Examples of such initiatives on the international scale are the *Chemical Regions for Resource Efficiency* project in which six European chemical clusters (including Stenungsund) collaborated around questions on recycling materials and biobased feedstocks,[1] and *SusChem*, a European technology platform for sustainable chemistry founded by the European Chemical Industry Council (Cefic), the European Association for Bioindustries (EuropaBio), and four other industry associations.[2] The Dutch chemical industry also formulated a vision for a sustainable chemical industry, although the very long time frame set for that vision – to reach the goal by 2080 – illustrates the slow rate of change in the industry(Loorbach, 2013). Despite these initiatives, deployment and diffusion of biorefinery technologies has been slow. One of the few initiatives for bio-based basic chemicals that have reached industrial production scale is the production of poly-ethylene (as well as other ethylene derivatives) from bio-ethanol by Braskem (de Andrade Coutinho, P L et al., 2013) while other global actors have not managed as well to introduce other types of bioplastics (Iles and Martin, 2013). This development has shown that it is possible to develop and market renewable chemical products, although it is still a niche product in a market dominated by fossil-based production.

Increasing petroleum prices from the turn of the millennium until the global economic crisis in 2008 and the rather high prices in the post-crisis years favored interest in renewable energy, also in the chemical industry. In terms of pressures for a transition, however, this is seemingly not nearly as strong as another important factor affecting the industry in the new millennium – the development of unconventional

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[1] www.regions4resource.eu [2017-10-27]
[2] www.suschem.org [2017-10-27]

petroleum and natural gas resources. The increasing production of shale gas has become an important new source of fossil raw materials for petrochemicals (Siirola, 2014). The greater availability of natural gas liquids (mainly ethane) has shifted global production of basic petrochemicals away from using naphtha from petroleum refineries, evident in most recent investments in North America and the Middle East (Amghizar et al., 2017). In the US, where the shale gas boom started, capacities to process the available ethane in petrochemical production facilities are lower than extraction rates, leading to increasing exports. Several European petrochemical firms have signed contracts and procured ships to import shale gas feedstocks from the US (Tullo, 2016). It has however also been argued that while shale gas has been a game changer for the chemical industry, the increased use of ethane could potentially open up possibilities for using renewable feedstocks for other chemical products (Bruijnincx and Weckhuysen, 2013).

4.3 The Swedish chemical industry

4.3.1 The emergence of a Swedish chemical industry

The Swedish chemical industry emerged in the 19th century, inspired by developments in Europe. In the early stages a major driver for the inorganic chemical sector was the production of, which was dominated by Fosfatbolaget. The organic chemical sector largely grew out of the Swedish forest industry: MoDo produced ethylene oxide from sulfite liquor available at their pulp mills, and Skånska Ättiksfabriken (later Perstorp) produced acetic acid, methanol and tar through dry distillation of wood. Fosfatbolaget also entered the organic chemical sector in the 20th century with their production of acetylene, used for vinyl chloride and subsequently PVC plastics (Berglund, 2010).

The Swedish chemical industry is peripheral in the contemporary, globalized structure.It is however an important industry in the domestic economy as it is one of the four large and influential energy intensive manufacturing industries together with the forest, mining, and steel industries. The industry employs around 33 000 people and accounts for around 17% of total Swedish exports. It is, as is the global industry, dominated by a small number of large MNCs through local subsidiaries, which account for the majority of employment and exports (Mossberg, 2013, Mossberg, 2016).

4.3.2 The petrochemical cluster in Stenungsund

The Stenungsund petrochemical cluster was established in the 1960s after several years of negotiations between MoDo and Fosfatbolaget - aiming to enter the growing petrochemical sector - and Union Carbide and Esso - American firms whose knowledge about markets and technologies was needed. During the decades that followed, the cluster grew with new production facilities and new firms entering the arena. However, MNCs rooted in the petroleum sector remained key partners to supply materials, technologies, and knowledge to the firms and facilities in the Swedish cluster. When Esso left Stenungsund, their steam cracker was acquired by Statoil, and when Union Carbide withdrew, Neste Oil took over operations of the polyethylene production (Berglund, 2010). The cluster currently consists of five organizations which are all subsidiaries to large MNCs: AGA (subsidiary of the Linde group, headquartered in Germany), AkzoNobel (Netherlands)[3], Borealis (Austria), Inovyn (subsidiary of Ineos, UK), and Perstorp (Sweden). Linde, AkzoNobel, Borealis, and Ineos are all ranked among the Global Top 50 Chemical Producers by the American Chemical Society (Tullo, 2017).

[3] Since the study was conducted AkzoNobel was split and the local subsidiary is now a part of Nouryon.

The center of the cluster is a steam cracker which uses naphtha, ethane, and other fossil feedstocks to produce platform chemicals such as ethylene and propylene. These platform chemicals are subsequently used in the other facilities for the production of different types of chemical products such as plastics, paint components, and specialties. The cluster uses approximately 5% of the total Swedish fossil fuel demand, making it a hotspot for debates about the transition to a low-carbon society. Around the five core organizations there is a network of service providers such as engineering consultancies, some of them also being subsidiaries of global SEFs, e.g. Jacobs Engineering. As the Stenungsund cluster is not located in direct proximity to neither key markets thatcould allow for forward integration, nor feedstock sources that could allow for backward integration, the firms in Stenungsund have during many years worked on strategies that allow them to remain attractive for continued operation and future investments. These strategies have for example focused on reducing production costs through energy efficiency.

Swedish environmental policy has for decades been progressive, in an international comparison, and forced industries to reduce their environmental impact in different ways (Lundqvist, 1997). After the oil crises in the 1970s energy policy aimed at reducing the dependency on oil and other fossil resources (Silveira, 2001). Sweden has since worked to reach a position as a pioneer in climate and environmental policy (Sarasini, 2009) and contemporary policy aims for the country to be one of the first fossil free welfare states. Sweden was early to introduce taxes and other policy instruments related to different environmental issues, e.g. one of the first countries with a tax on CO_2 emissions (OECD, 2014) and a refunded payment scheme for NO_x emissions (Sterner and Turnheim, 2009). The Swedish chemical industry has thus been forced to comply with strict energy and environmental policies throughout the years. This includes regulations on different types of emissions, e.g. mercury and other harmful substances, improving energy efficiency through policy instruments such as the “Program for energy efficiency in energy intensive industries” in which several of the firms from the Stenungsund cluster participated, and utilizing industrial waste heat in local district heating systems, which in Stenungsund allows the energy in the district heating system to be supplied almost completely with waste heat from two of the chemical industries.

The firms in the cluster have made significant investments in new and improved production technologies in the past decade. These investments largely follow traditional, global logics in the sector aiming for upgrading and expanding existing production. Following the expansion of shale gas production in the USA mentioned above imports of ethane from the US to Stenungsund increased, necessitating local investments in port infrastructure and storage facilities, expecting that for at least ten years it will be beneficial to use North-American ethane. The furnaces at the Borealis steam cracker are also being revamped to improve efficiency and production capacity using conventional feedstocks, i.e. naphtha and ethane. In 2016 Inovyn decided to invest in a new production unit for chlorine. The new unit uses membrane technology and replaces the old mercury process, following new European legislation after the Minamata convention. This is a large investment which follows the logic of reducing the environmental impact of chemical production only after increasing pressure from national and international regulators, while at the same time improving the energy efficiency of the process significantly (reportedly up to 20 %). Perstorp was the first firm in the cluster to engage in bulk production from renewable feedstocks with their biodiesel production facility that was inaugurated in 2007. This was however not a change in conventional processes for the production of chemicals but a decision to enter a new market – biofuels. Although investments have been made by the different actors aiming to improve the efficiency and reduce the environmental impact of production as well as using renewable feedstocks, the transformative potential of these investments was clearly limited. However, in 2011, the firms in the cluster started collaborating and formulated a shared vision for a sustainable chemical industry based on a transition to renewable and recycled feedstocks. This initiative is explored further in the next section.

4.4 Local sustainability initiatives: *Sustainable Chemistry 2030* and *Forest Chemistry*

In 2011 the firms in the cluster started an initiative around a shared vision called *Sustainable Chemistry 2030* (SC2030) which states:

> *"In 2030 Stenungsund will be a hub for the manufacturing of sustainable products within the chemical industry. Our business is based on renewable feedstocks and energy and contributes to a sustainable society".*

The vision was multi-faceted and included several different parts: using electricity from renewable sources to power the processes; using biogas, bioethanol and other renewable feedstocks for the production; increasing energy efficiency through energy integration across different processes; recycling plastic materials as feedstock for the production of new plastics. This vision thus contained parts which were not all relevant for all firms – e.g. recycling of plastics is of no direct relevance for the firm producing pure oxygen and other gases. The vision did however create a platform for collaborating around the ambitious target of a local socio-technical transition as well as more conventional topics such as improved energy efficiency through process innovation. A significant part of the collaborative work was to communicate what the industry, and in particular the involved firms, are doing with respect to sustainability. This included communication about how their products enable both energy efficiency and reduced environmental impact of other products and services, e.g. water soluble detergents for cleaning and advanced electrical power cables for renewable energy installations. Furthermore the firms also connected the work with the shared vision to other investments and projects led by the individual firms, e.g. production of biodiesel and other products . Recent additions to the group of renewable chemicals produced by one of the firms are new paint components which are partly or completely (available in different grades) made from renewables. That this is communicated under the label of SC2030 shows how this is seen as a significant accomplishment and break from the regime logics.

The initiative is centered around the use of renewable or recycled feedstocks for the production of current products and energy efficiency improvements in the cluster. These are all technologies which assume a development of the cluster, the products produced, and interdependencies of the firms to remain approximately the same as today. Research into new technologies was focused on ones that would be compatible with the current technological setup in the cluster and produce similar outputs. By focusing on so called drop-in solutions, such as ethylene from ethanol, the barriers for introducing products based on renewable feedstocks would be lower (as the products themselves are in fact not new) but this strategy also requires technologies for renewables to fully comply with standards and procedures established within the fossil regime.

The actors involved in the initiative were the five large chemical producers in the cluster, which although they had been co-located and trading energy and products with each other for a long time had no tradition of working together in innovation or development projects. Although the firms in the Stenungsund cluster are not direct competitors as they produce different types of products intended for different markets, e.g. plastics for cables and surfactants for paints, the parent MNCs are competitors on other markets. This made it difficult to formalize the collaboration as sharing information with competitors is a sensitive issue for MNCs. The initiative was thus managed rather informally by a steering group of local senior management representatives from each of the firms, who were also engaged with presenting it at conferences and other external communication efforts. However, RDI managers were not directly involved in the initiative, indicating that it was not primarily a project for collaborative RDI. RDI departments of the firms in Stenungsund are primarily focused on specific product and process development, e.g. the large RDI department of one of the firms is primarily working on highly specialized materials for a specific niche with extreme quality requirements compared to bulk applications of the same product, which is not connected to the question of working with new or recycled feedstocks. The steering group had monthly meetings which enabled the building of trust between senior management from the different firms, but the work related to the vision was also largely kept apart from the regular RDI activities of the firms, which are to a significant degree decided by HQ guidelines and priorities.

MNC headquarters were in some cases reportedly kept unaware of the initiative, indicating the controversial aspects of the local initiative. Interviewees stated that in some cases there was acceptance for the initiative and its efforts from MNC HQs, but in several cases only conditional upon the fact that the initiative would not require any funds or resources. Interviewees from another of the firms with significant local RDI resources expressed how their possibilities to participate in projects related to the initiative are completely dependent on external funding as they deviate too much from priorities set by HQs. They have to apply internally for RDI funding, which creates a competition for resources within the MNC and limits their possibility to advance a local agenda as projects have to be approved by distant HQ managers.

The initiative was to a large degree sustained by a few very engaged individuals and the initiative seemingly lost some of its traction when these individuals could no longer remain as dedicated. After reorganizing and streamlining innovation activities in one of the firms the person who had been representing the firm in the steering group no longer had dedicated working hours to spend on the initiative. Instead another position was created and focused on sustainability, but mainly working with external communication and internal education and not at all with the SC2030 initiative and its related projects. Thus, without fully withdrawing from the initiative the possibility to participate was effectively reduced to a minimum. The CEO of one of the other companies, who was very involved in the initiative, switched to working with other network activities in the region, and although he remains in close contact with the actors in the cluster he is no longer active in the day to day activities.

Connected to the work with the vision the actors have been working with influencing rules and regulations. They have met with policymakers on both regional and national level, aiming to inform and influence them about the need for the type of change that is outlined in the vision and create a more favorable institutional context. This work has been aiming to change national and European regulations for recycling of chemical products such as plastics from fossil resources. Working directly towards policymakers was perceived as important as the actors felt that the knowledge about their global context and specific challenges was limited within the policy sphere. The actors trade most of their products on global markets, on which they stress that it is difficult to gain a premium for “being green” as the products are identical down to the molecular level: "[Renewable] products do not have to be cheaper and better, but not so much more expensive and just as good".

Although actors claim it may be possible to sell certain green products with a premium on some markets in which there is reasonable willingness to pay extra for it, Scandinavia and parts of northern Europe were pointed out, these markets are very limited in relation to the total exports. Further, the firms are positioned far from end consumers which makes it difficult for them to show the sustainability of their products to users of more complex products of which the chemicals finally become a part. As one of the interviewees rhetorically asked: "Did you buy that phone because the surface of the display is biobased? … When you buy kitchen utensils or clothes or food, do you think of the packaging – whether it is based on a bioplastic or not?".

Although most of the MNCs according to their annual reports prioritize sustainability issues highly and have global sustainability departments, , none of them are located in Stenungsund or directly involved in the SC2030 initiative. Furthermore, the focus on introducing and using renewable feedstocks is not highlighted in any of the MNC sustainability reports from the last years. This is thus clearly a local initiative and effort. The reason for the Stenungsund subsidiaries to engage with this question is, according to several of the interviewees, the need for a specific niche due to the peripheral position of the cluster, and the availability of renewable resources in Scandinavia – primarily raw materials from forests which do not compete directly with food production. Another example of the different perspectives on sustainability on the local and global level is how the sustainability work done in Stenungsund is presented on some MNCs' web sites- focused solely on the delivery of waste heat from the production facility to the local district heating grid. In this way the local efforts are reduced to another energy efficiency improvement project while ignoring the more transformative aspects.

Forest chemistry was a collaborative project between the Stenungsund cluster and a pulp and paper industry cluster around the city of Örnsköldsvik in northeastern Sweden. Although the forest and pulp industry had been involved in establishing the Swedish chemical industry decades ago, collaborations between the actors had not existed for many years. The project was initiated by a manager from the Örnsköldsvik cluster who started a dialogue about shared sectoral challenges and possible avenues for collaboration. The chemical industry firms saw the collaboration with the forest and pulp sector as a promising avenue – wanting to avoid the previously intense debate on competing with food crops ("food vs. fuel") but seeing opportunities for using a large, renewable resource, which is already exploited by the pulp and paper industry, as a new feedstock base. They did however receive limited support from their HQs as using the forest as a resource is a more sensitive issue in other parts of Europe than Scandinavia. The project was instead enabled through financial support from Vinnova, the Swedish innovation agency.

The project focused on the production of three important chemicals – olefins (mainly ethylene), methanol, and butanol – using different technology platforms – gasification of wood and subsequent chemical synthesis or fermentation of wood and subsequent chemical conversion of ethanol. A key aspect for the choice of products and technologies were the availability of "large market volumes providing for bulk production potential and the ability of the chemicals to fit into existing infrastructure – so called drop-in chemicals" (Joelsson et al., 2015). Although the project concluded that the technologies for producing butanol and olefins from ethanol and methanol were commercially available, there were too large uncertainties and risks associated with the necessary steps towards a production of platform chemicals based on biomass gasification or fermentation. Thus, the third stage of the project was the installation and testing of a pilot for the production of methanol from black liquor at a pulp mill. This was described as "the least interesting choice" as the novelty and scale of this technology was limited, but the only realistic one as the Vinnova program could not accommodate funding a pilot plant for the other options and the risks and uncertainties were too large for the firms to make the necessary investments on their own. Although sharing the risks in biorefinery investments through collaborative consortia has been suggested as a way forward, this has proven to be difficult. As one of the interviewees stated: "It is great fun to attend the first kick-off meeting, to sit down and talk about doing things and investing. Then you are writing a consortium agreement and start looking at your IP rights and interests, and thereafter you are getting closer to an investment – who is paying for it and who is going to benefit from it?"

As described above the local actors connected to the initiative have been able to advance a transition agenda for a more sustainable chemical industry, although they have not reached the point of making any full-scale investments. The agenda has been both supported and suppressed by local as well as global factors, which are summarized in Table 1.

Table 1. Summary of findings

	Actors and networks	**Technologies**	**Institutions**
Support			
Local	Involved and willing individuals in subsidiaries; non-competitive local network; collaborations with academia and institutes	Access to bioresources from forests and forest industry; established industrial infrastructure	Progressive environmental discourse and policy; informal and trusting culture
Global	Scientific competence for RDI in MNCs	Inspiration from processes for renewable chemicals and plastics in Brazil	Global climate and sustainability discourse; science-based innovation tradition
Suppression			
Local	Lack of knowledge about bioresources and their processing	Sunk investments in petroleum based production; focus on drop-in chemicals	Limited possibility for local niches for sustainable products;
Global	MNC HQs setting priorities; limited collaborations with bioresource sectors	High availability and low cost of fossil feedstocks	Global competition and risk aversion; no green premiums for bulk chemicals

5 Analysis and discussion

5.1 Global regime pressure

The discourse on sustainable development and climate change has clearly not surpassed the chemical industry, but on a global level the regime seems to have found a way to deflect any pressure on the industry for structural change. By arguing that their products are in fact the enablers of the renewable energy expansion the chemical industry discursively allies itself with the transition away from fossil resource dependency. However, is the industry simultaneously rejects that the transition heavily implicates the chemical industry itself, although it is undeniably completely dependent on fossil resources. This argumentation is mirrored locally in communication about how some products are needed for renewable energy solutions, and that RDI investments have been focused on these applications.

Although efforts have been made regarding communication about the initiative, the industry suffers from being far removed from end consumers when it comes to consumer pressure. The chemical industry does not have a good reputation among consumers.Consumers' understanding of the complex value chains in the industry is low as the chemical products are often only part of more complex products with other primary values for users. The conflict between the local initiative and the global regime is mirrored in how sustainability challenges are framed and handled, with a considerably more conservative framing persisting on the global level, focused on energy efficiency and reducing direct emissions of harmful substances. This clearly showcases the institutional contradictions that exist between the local and global level. The multi-faceted nature of the local initiative is thus reduced and forced to follow regime logics which focus on energy efficiency and sustainability in other sectors.

5.2 Local forces

The local institutional setting has clearly been a driving force for this development in several ways. The informality of Swedish business culture is reflected in the informal setup for managing the initiative, largely built on personal trust between the individuals in the steering group. Swedish policy has for decades emphasized the importance of dealing with the environmental impact of industrial manufacturing, both for local issues such as toxic emissions to the Baltic sea and global issues such as climate change. This has clearly led to an awareness of the significance of these issues among the public as well as the individuals active in the initiative.

The rationale behind the forest chemistry project that aimed to generate innovations in the boundary between the chemical and forest industries is closely linked to the idea of developing the bioeconomy. The bioeconomy has become a prominent aspect of Swedish innovation strategies (de Besi and McCormick, 2015, R. Meyer, 2017) and is in line with the Scandinavian focus on the forest as a bioresource to be exploited for industrial purposes (Kleinschmit et al., 2014), e.g. through the development of biorefineries – a technological pathway that has been promoted and supported extensively in Sweden (Hellsmark et al., 2016). The project also aimed to reconnect industries that had previously had strong connections, but which today are isolated from each other. The established networks that these actors are part of are thus inadequate for integrating the different types of knowledge and capabilities that need to be combined to innovate for a biobased chemical industry.

As described earlier the local sustainability initiative was set up with a highly informal structure, which has reportedly worked out well. However, despite the trust established through this collaborative work and the fact that the firms locally are not competitors, it remains difficult to establish more formal collaborations. Significant attainable energy efficiency improvements have been identified in work related to the initiative, both in the context of adding different possible biorefinery processes to the cluster (Hackl and Harvey, 2015) and optimizing the current structure with its connections to the district heating system (Morandin et al., 2014). Apart from the high technical complexity required to achieve the largest energy savings, also when aiming for more moderate efficiency improvements the measures require collaboration between and investments by several or all of the firmswhich has been very difficult to realize (Mossberg et al., 2014).

5.3 Tensions

Looking to issues of tension between the local initiative and the global regime several aspects have been identified. The initiative met several difficulties in trying to go outside the regular innovation process, which was a problem in the organizations that have streamlined and structured innovation processes to follow globally standardized procedures. There is thusless leeway for local managers to engage in projects that they find interesting from a local perspective. The internal competition for resources in the MNCs creates obstacles for participation in the type of exploratory and collaborative work that may be needed to find new forms of innovation. This reduces the number of possible pathways local initiatives can explore and strengthens the dominance of regime logics. The example of the forest chemistry project shows this clearly. Forest resources are seen as one of the most sustainable source of biomass in the Swedish discourse and by the participants in the sustainable chemistry initiative, but their possibilities to participate and dedicate resources to explore this possible pathway were limited as the understanding was seemingly not shared by HQ decision makers.

Further, the structure of the sector is itself a problem for innovation related to the use of renewable and biobased materials. The actors that could potentially engage with these issues are far removed from consumer pressure for sustainable production. The consumers in turn have little understanding for the long and complex value chains of chemical products and materials. Markets for basic or platform chemicals are global and focused completely on business-to-business logics, perpetuating logics of economic competitiveness that largely depend on economies of scale with which biobased production is currently unable to compete. As home markets are too small for subsidiaries to focus on they also have difficulties in establishing local niches for more sustainable products. The actors also find themselves distant from other subsidiaries within the same MNC, both in geographic and organizational terms, making it difficult to share information and resources for exploratory innovation for sustainability. Although this could support collaboration with partners in the proximity, this is hampered by the fact that although other actors in the region may not be direct competitors the MNCs are competitors in other segments or markets. Although local managers find the local partnership important it is difficult to grow partnerships with other actors in the industry as the expectations on such collaborations are inconsistent between the local and global level. Investment priorities are set by MNC HQs making these priorities based on logics of competition, which creates barriers for the collaborative efforts needed, also for uncontroversial energy efficiency projects. In this way the global regime limits what is possible to achieve not only for the more radical part of the local sustainability agenda but also for energy efficiency.

To summarize, we find that there are four main dimensions of multi-scalar transition dynamics which have played important roles in shaping the development of the local sustainability initiative. These dimensions largely stem from the global structure of the sector and can be expected to play an important role in other contexts which share similar institutional structures. The four dimensions are summarized in Table 2 below.

Table 2. Summary of multi-scalar dynamics dimensions.

	Explanation	Examples
Inadequate networks	Alliances and partnerships formed on a global level are	Synergistic collaboration between local firms hindered by global competition between MNCs; weak partnerships with bioresource sectors

	inept for local transition requirements	
Inconsistent aims and expectations	Global and local managers have different ambitions and aims for the future	Local managers proud to potentially be frontrunners in the transition but bound by global rationality to focus on incremental improvement and profitability
Institutional contradictions	Incoherent and/or contradictory rationalities on the local and global level	Sustainability has been institutionalized in the global regime as compliance with emission and OHS regulations, while the local initiative challenges the material lock-in of the sector to fossil resources
Internal competition	Competition for resources – knowledge, capital etc. – within global organizations	Limited possibilities to fund innovative projects locally as priorities and budgets for innovation set by distant HQs; competition with other production sites for investments and resources

6 Concluding remarks

The paper has shown how initiatives for sustainability transitions are not just local affairs. They interact with and can be supported as well as suppressed by highly internationalized institutional rationalities that can be described as global socio-technical regimes. In the case study of a sustainability initiative in a Swedish chemical industry cluster we identify four dimensions of dynamics that bridge the local and the global; institutional contradictions, internal competition, inadequate networks, and inconsistent aims and expectations. Each of these contributes to shaping pathways for local transitions in systems that are dependent on developments outside the local and national context. It also indicates that although national policy can generate conducive conditions for progressive transition agendas, there are factors at play that are not controlled by national policymakers. Careful consideration of how local, national, and global institutions interact is thus needed for transition policies to be effective.

The findings point to the importance of not limiting the study of transition dynamics to the local or national level, but to also include multi-scalar dynamics. Future research should study the relevance of the identified dimensions in other systems and sectors to corroborate the findings, as well as further exploring how actors perceive and potentially find ways to work around these dynamics in local transition initiatives. Furthermore, interactions between policies at different scales interact should be studied to better understand how different types of policies can best support transitions in systems dominated by global regimes.

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8 Declarations of interest

The authors have no conflicts of interest to disclose.

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