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Abstract

Arguably, the debate on innovation-based structural change in Evolutionary Economic Geography (EEG) reflects a strong dichotomy between on-going continuation and radical change of industrial path development. In this paper we argue that radical innovation activities can occur within existing paths without necessarily leading to their dissolution. Departing from a systemic perspective of path development, we propose a stage model of path transformation. We outline how radical change becomes initiated, reinforced and finally consolidated in established industrial paths. Particular attention is devoted to the ways in which multiple actors – influenced by 'the past' and driven by visions and expectations (that is, 'the future') – exert agency to stimulate asset modification processes that are assumed to underpin path transformation and the reconfiguration of the wider support structures. The framework is applied to the analysis of the automotive industry in West Sweden, which is currently transforming towards the development of self-driving cars.

Keywords

Path transformation, evolutionary economic geography, stage model, assets, agency

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1 Introduction

The rise of Evolutionary Economic Geography (EEG) has led to a renewed interest in the mechanisms and processes of innovation-based development of industrial paths[1]. The debate is characterised by a strong dichotomy between on-going, gradual change driven by incremental innovations leading to minor adjustments of existing paths on the one hand and more radical change triggered by disruptive innovations believed to underpin the rise of new paths on the other hand. Reflecting a broader scholarly interest into how novelty is generated (Morgan 2017), the past few years have witnessed a shift of attention towards the latter (MacKinnon et al. 2019).

This paper seeks to place a critical spotlight on this dichotomy by offering a more nuanced view that focuses attention on how radical innovation activities may take place within existing, fully established regional industrial paths. We argue that radical innovations can happen 'on the path' and do not necessarily lead to its dissolution. Path transformation implies that the regional industry and its wider set-up (that is, the regional support structures that back its continuous development) are significantly altered. We contend that due to the disruptive nature of radical innovation, one can hardly assume such transformations to be linear and abrupt but rather to be complex and long-term processes, featuring both continuity and change.

The aim of this paper is to contribute to a richer understanding of how a radical transformation of existing industrial paths unfolds over time. To address this question we draw on recent systemic conceptualisations of path development and propose a stage model of path transformation. In the next section we will provide a critical review of conventional EEG accounts of regional industrial path development and their shortcomings. In section 3 we outline our conceptual model. This model is informed by broader conceptualisations of regional industrial change that have recently been developed to challenge currently dominant interpretations of regional industrial path development. Our model centre stages the nature of asset modification processes that underpin the transformation of mature industrial paths (and the wider support structures they are embedded in) and explicates how multiple actors and their agency – influenced by the past and driven by future prospects – engage in radical 'on path'

[1] Drawing on the definition of a newly created path by (Binz, Truffer, and Coenen 2016, 177), an existing path can be defined as 'a set of functionally related firms and supportive actors and institutions that are established and legitimized […]'.

changes. We explicate how these processes differ between three stages of path transformation, that is, the initiation stage, the acceleration stage, and the consolidation stage. Section 4 applies the stage model to the empirical case of the automotive industry in West Sweden, which is currently undergoing major change processes triggered by the advent of self-driving cars. Our analysis of the empirical findings largely confirms our conceptual arguments but also identifies some 'deviations' that require further research and explanations. Finally, section 5 concludes and outlines several key issues for future research.

2 Regional industrial path development: EEG perspectives

Innovation and adaptation processes are place-dependent phenomena reflecting specific contexts and conditions (Martin 2010; Martin and Simmie 2008). Evolutionary Economic Geography (EEG) explains the current state of affairs from history (Martin 2010; Martin and Sunley 2006), placing explicit emphasis on assets, skills and competencies developed in the past, which influence present and future choices (Martin and Sunley 2010). These essential ideas underpin the notion of 'path dependence'.

At the core of EEG thinking is the duality of continuity and change in regional industrial evolution. Continuity in an evolving system is understood as on-going, gradual change in order to respond to constant competitive pressures (Martin 2010). EEG understands this form of steady adaptation as the norm, while also acknowledging the possible occurrence of events that may trigger radical discontinuities of economic development. This dichotomy, however, is problematic, because it suggests that gradual change is happening 'on the path' (Martin 2010), while radical change results either in path dissolution or in the creation of new paths. We challenge this view by arguing that radical innovation activities may occur within mature industrial paths and institutional settings. We refer to such processes as 'path transformation', that is, radical, innovation-based forms of path development, where an established path and the regional support structures it is embedded in are undergoing major change over a period of time.

EEG accounts of innovation-based path development have significantly enhanced understanding of how regional structural change unfolds over time. However, recent contributions have highlighted several shortcomings of EEG models. First, EEG portrays path

development as a firm-driven process, neglecting the importance of other actors such universities (Vallance 2016) and policy makers (Dawley 2014; Dawley et al. 2015) and their agency. Second, there is a strong focus on the redeployment of technological and skill assets. Other types of assets such as for instance institutional endowments (MacKinnon et al. 2019; Maskell and Malmberg 1999) tend to be overlooked. Further, recent work suggests that it is not only the re-use of existing assets that matters. Since established innovation systems are often poorly equipped to support radical change and path transformation, creation of new assets and the destruction of old constraining ones are vitally important. One also needs to acknowledge that such asset modification processes may be contested. Innovation-based change might lead to intra-path and inter-path competition over scarce assets (Frangenheim, Trippl, and Chlebna 2018). EEG has thus far hardly paid attention to the potentially conflictual nature of path development and transformation. Third, EEG offers substantial insights into how 'the past' influences structural change but has thus far done little to incorporate the role of 'the future' in the form of visions and expectations into analyses of path development (Hassink, Isaksen, and Trippl 2019). From a sociological perspective, future prospects are a vital driver for engagement and agency of relevant actors (Emirbayer and Mische 1998).

Recent work has begun to integrate the insights outlined above into a systemic perspective of path development (Trippl et al. 2019), arguing that the rise of new and the renewal of existing paths require substantial asset modification processes. Redeployment of existing assets, creation of new assets and destruction of old constraining assets are said to reflect reconfiguration processes of (multiscalar) innovation systems and are seen as brought about by firm-level and system-level agency.

In order to better understand how such processes take place in mature industries facing radical change, we propose a stage model of path transformation and examine the ways in which multiple actors – influenced by the past and driven by future prospects – engage in asset modification and system reconfiguration throughout the process of path transformation.

3 Towards a stage model of path transformation

This section provides a more detailed account of key elements of recent broader conceptualisations of path development, which have begun to complement established EEG

perspectives (section 3.1). Building on these insights, we outline how path transformation may unfold through three phases (section 3.2).

3.1 Setting the scene: key factors brought forward in recent conceptualisations of path development

The idea that **historically grown structures** set the possibilities for socio-economic actors in the present is at the very core of evolutionary thinking: previous choices and activities influence subsequent ones (Martin and Sunley 2006, 409). The regional asset base is seen to reflect previous rounds of path development and serves as a platform for future ones (MacKinnon et al. 2019; Trippl et al. 2019). In this regard, different types of assets constituting the regional asset base can be identified (MacKinnon et al. 2019; Maskell and Malmberg 1999): natural assets (resources), infrastructural and material assets, industrial assets (technological and firm-based competences), human assets (skills and knowledge), and institutional endowments (rules, routines and norms).

Natural resources (such as sources of energy supply) and infrastructural assets (digital as well as material ones) form the often-overlooked basis for economic activity and might be of vital importance for economic decisions. Industrial assets refer to the competences, routines and networks of firms located within the region. They are a core focus of conventional EEG perspectives, and, in a Schumpeterian sense, seen as the driver of economic evolution and diversification activities (Schamp 2017). Human assets not only imply the regional labour force and their skills, but also knowledge created in organisations like research organisations and higher education institutes, which might be decisive for the adaptive capacity of regional economies (Vallance 2016). Furthermore, institutional assets, which constitute 'the way of doing things' matter. Place specific institutional endowments (Rodríguez-Pose 2013) describe formal and informal mechanisms developed in the past that are creating the 'rules of the game' (North 1990). One the one hand, they provide stability for socio-economic actors. On the other hand, however, they tend to favour the old over the new and thus might hamper innovations and change (Zukauskaite, Trippl, and Plechero 2017). Industrial change is therefore often contingent on institutional change.

Regional industrial path development and transformation will only unfold if **local (and non-local) actors** harness and valorise the value rooted in the regional asset base (MacKinnon et

al. 2019). In contrast to firm-centred views prevailing in conventional EEG models, systemic perspectives of path development (Isaksen and Trippl 2016) suggest adopting a multi-actor approach. In line with this view, our framework appreciates the role played by non-firm actors such as universities or research institutes (Tanner 2014; Vallance 2016), policy actors, support organisations, intermediaries (Dawley 2014), and so on. These actors may fuel path transformation by pursuing system level changes. This calls for consideration of what is called institutional entrepreneurship (Battilana, Leca, and Boxenbaum 2009) and system level agency[2] (Isaksen and Jakobsen 2017) in addition to firm level agency.

Yet, to understand the complexity of agency, one has to grasp it in its inter-temporality: agency refers to the '*capacity to contextualise past habits and future projects within the contingencies of the moment*' (Emirbayer and Mische 1998, 963). While our model acknowledges the habitual aspect of agency through the relation between the regional asset base (involving routines, norms etc.) and actors, we particularly highlight the key role of **visions and expectations** in moving the process towards path transformation forward. By so doing, we complement the prevailing focus of EEG models on how the past influences path development by explicitly recognizing the role of the future in shaping transformative activities (Hassink, Isaksen, and Trippl 2019).

An act is always related to '*a state not yet in existence, and which would not come into existence if something were not done about it by the actor*' (Parsons 1968, 45). In accordance with this premise, (Steen 2016) highlights the generative power of the future in path development processes. Accordingly, socio-economic actors can be understood as strategic entities that pursue goals and undertake activities to achieve them. Actors' visions and expectations thus contribute to the mobilization of resources, experimentation efforts, network activities and so on (Steen 2016).

Visions can be individual or collective in nature. While contested visions might be a source of conflict and a barrier for change (Wanzenböck et al. 2019), shared visions provide important orientation and directionality for actors (Weber and Rohracher 2012). Future prospects are a matter of continuous re-evaluation and they change over time. The emergence of joint

[2] Agency can be defined as deliberate and purposive actions or interventions by actors in order to produce particular effects (Emirbayer and Mische 1998; Hassink, Isaksen, and Trippl 2019; Sotarauta and Suvinen 2018).

expectations often takes time, requires efforts by system level agents (Sotarauta, 2009) and benefits from geographical proximity (Coenen, Raven, and Verbong 2010; Steen 2016).

Path transformation through asset modification

Due to its radical nature, path transformation comes with profound alterations of historically grown regional structures, implying a modification of the regional asset base (MacKinnon et al. 2019). As Maskell and Malmberg (1999, 10) point out, regional assets can be '*modified or reconstructed by the deliberate and purposeful action of individuals and groups within or outside the area*'. Accordingly, actors – influenced by the past and driven by future prospects (Emirbayer and Mische 1998) – are engaging in asset modification, using different strategies throughout the path transformation process.

Conventional EEG perspectives are mostly concerned with existing regional assets and how they are re-used or recombined for path development. Recent contributions extend this view and argue that it is not only the recombination of existing assets but also the creation of new assets and the destruction of old assets (Trippl et al. 2019) that are required for transformation to succeed. While each of these processes of asset modification is vital for successful and lasting change, we bring forward the argument that the relative importance of them is changing throughout the unfolding of regional industrial path transformation.

Different strategies of regional asset modification are key not only to alterations within the industry but also to create a wider supportive environment for path transformation. This is because established asset configurations support and stabilise pre-transformation activities. Put differently, they are often well aligned to existing paths and are thus poorly equipped to provide the capabilities, infrastructure, or institutional settings necessary for a radical shift driven by a disruptive innovation to unfold (Tödtling and Trippl 2013). Changes of the regional asset base thus involve the de-alignment and re-alignment of established asset configurations, and, as noted above, the creation of new and the destruction of old ones. Such processes might involve conflicts of interests. They are thus often controversial and might be contested.

Finally, path transformation per definition is representing a radical, innovation-based form of alterations of well-established paths and the regional structures they are embedded in. Yet, such

processes of change are highly influenced by national or even global dependencies, influences and events (Martin 2010; Simmie and Martin 2010). How such shifting conditions are ultimately affecting the development of a certain place depends on local characteristics (Trippl, Grillitsch, and Isaksen 2018). Accordingly, these two influences are not mutually exclusive: while one has to acknowledge the multi-scalar nature and geographical complexity of regional economic evolution, some regions still remain better suited than others to deal with extra-regional pressures.

3.2 The unfolding of industrial path transformation

The key factors discussed above, that is, historically grown structures, number and connections of relevant actors, the role visions play for their agency and the resulting asset modification processes can be expected to vary between early and more advanced phases of industrial reorientation. To capture these dynamics, we suggest a stage model[3] of path transformation, distinguishing between three phases, namely, initiation stage, acceleration stage, and consolidation stage[4].

However, while a conceptualisation based on the notion of stages might evoke ideas of linearity or universality, our model points to ideal-type processes and implies no deterministic claims. We acknowledge the possibility of failure at any stage of adaptive transformation. Moreover, some of the key processes may lag behind or outpace others and thereby deviate from the 'typical' (Markard 2018). Additionally, external shocks or newly emerging problems or opportunities might lead to setbacks or leaps forward.

[3] Arguably, stage models of economic development are popular within the economic geography and regional science literature. Recent debates centre around cluster life cycles (Menzel and Fornahl 2010), the 'path as a process model' (Martin 2010) and Foray's (2014) conceptualization of the Entrepreneurial Discovery Process (EDP). The latter has gained considerable attention in the context of scholarly discussions about smart specialisation. EDP implies an episodic course of development towards regional structural reorientation. The EDP is driven by entrepreneurial knowledge, recognition of market potentials, experience and visions, opening up a new domain of opportunities for a whole segment of an industry (Foray 2014). For this discovery phase to happen in the first place, policy support is often needed as the entrepreneurial knowledge might be fragmented and distributed across companies, universities and other actors. Successful reorientation depends on a larger number of actors to shift ('entry') to new fields. Reaching a critical mass in this 'phase of increasing returns' is necessary for broader structural change to take place.

[4] Similar phases have been used in the transition literature to capture the course of development of socio-technical change (Jedelhauser and Streit 2018; Markard 2018; Rotmans, Kemp, and van Asselt 2001).

Initiation stage

The first stage, i.e. the initiation stage, is usually enabled by new possibilities or emerging pressures. Path transformation might be initiated by disruptive events taking place within or outside the region, like crisis, the emergence of new competitors, shifts in the market situation or radical innovations (Martin 2010; Simmie and Martin 2010). Such discontinuities challenge historically grown structures.

In this phase, many actors are still focusing on their established fields of action, while only a few first movers engage in early experimentation (Foray 2014). Path transformation is often initiated by innovative entrepreneurs who deviate from existing products and processes (Garud and Karnøe 2001; Grillitsch and Sotarauta 2018) and exploit emerging opportunities. This rather small number of early movers may be large corporations or young and agile start-ups. Early transformation-related activities may also be induced or supported by system-level actors. Knowledge generated in universities or new policy incentives may be sources of path transformation (Dawley 2014; Sotarauta and Suvinen 2018).

The expectations and visions in the initiation stage are more often than not ambiguous. On the one hand, pioneers of change seek to exploit emerging opportunities. Driven by strong beliefs in the innovation, they focus on experimentation and find themselves in 'early sense-making processes'. On the other hand, however, radical innovations that challenge dominant paradigms and mind-sets are often characterised by great uncertainty. There is no clear vision of what the outcome might actually be (Sotarauta and Mustikkamäki 2015). This leaves many actors in a rather observant state, waiting for the uncertainties of new activities to diminish (Kulve 2010; Sotarauta and Mustikkamäki 2015).

Many assets – like technological competencies or favourable regulations – do not pre-exist for completely new solutions (like self-driving cars, which are in focus in the empirical part of this article). There are strong reasons to assume that pioneers of change driven by the belief in transformation activities do not only engage in redeploying and recombining existing assets (Boschma and Frenken 2011) but are also targeting *missing assets* in the initiation stage, that is, they are expected to engage in new asset creation activities.

In the initiation state, it is only few knowledgeable non-firm actors who create the necessary regional assets (e.g. educational programmes to foster the generation and transfer of knowledge, fitting regulations and norms, etc.) They often have to work around institutionalized logics of highly aligned structures in this early stage (Sotarauta and Mustikkamäki 2015).

Acceleration stage

In the acceleration stage, activities related to transformative reorientation experience intensification. Opportunities created in the initiation stage are increasingly utilised, newly established structures serve as a foundation to build upon. The process towards transformation gains momentum due to reinforcing effects. Yet, many assets are still 'locked-in' and oriented towards old activities, resulting in a 'co-existence' of old and new structures within the industry and the wider setting it is embedded in.

The spreading of economic knowledge demonstrates future opportunities to a wider number of actors (Foray 2014; Grillitsch and Sotarauta 2018). Thus, in this phase more and more incumbents are following the early movers. They are reorienting their activities, longing to complement or exploit opportunities created by the pioneers of change (Simmie 2012). At the same time, the number of spin-offs and start-ups might increase as well. Similarly, a growing number of system-level actors are expected to engage in asset modification and regional reconfiguration endeavours.

Moving beyond the initial stage of path transformation requires collective belief formation (Sotarauta and Mustikkamäki 2015). This is a challenging issue. While the spreading of economic knowledge (Foray 2014) is increasingly signalling potential future opportunities, there are often conflicting opinions about the route and direction towards path transformation. Therefore, system-level agency is expected to play a key role in this stage of development, contributing to setting the agenda and thereby creating a joint vision by bringing together different actors, resolving conflicts and shaping interpretations (Sotarauta 2009).

Despite varying expectations, we assume that *reorientation of existing assets* gains momentum in the acceleration phase due to the growing recognition of promising future prospects. An

important question is how to unlock assets in use or to 'import' the necessary knowledge and other resources from elsewhere in order to jump on the bandwagon. This can either take place within an organisation (e.g. R&D, in-house innovation, recruitment of skilled labour) or by acquisition of assets (e.g. mergers and acquisitions) and collaboration with other actors. Established organisations may unlock and reorient existing assets and recombine these with new (related) ones (Boschma and Frenken 2011). This might enable incumbents to regain their competitive edge.

Additionally, in the acceleration phase a broader regional asset base (including complementary infrastructural, human and institutional assets) facilitating the transformation activities is being shaped. A growing number and variety of 'actors of change' is undertaking efforts to deliberately turn a regional environment that constrains path transformation into an enabling one (Miörner and Trippl 2017). System-level actors can for instance reorient activities within research labs or provide the needed infrastructure. Re-alignment processes are gaining momentum. Organisations and institutions are formed that represent the views and goals of new actors or of reorienting incumbents. At the same time, regional assets still oriented towards pre-transformation activities are increasingly questioned due to their incompatibility with newly emerging structures (Martin 2012).

The intensification of path transformation activities may come with particular challenges. They might result from growing requirements the old regional structures cannot meet or from growing competition over scarce assets. The former may lead to conflicting ideas concerning the direction of change (varying expectations) or legislative difficulties (testing, insurance, regulations, risk-management, etc.), the latter to inter-path conflicts (recruitment of skilled labour force, funding, political and public attention, etc.) (Frangenheim, Trippl, and Chlebna 2018) or problems related to the behaviour of consumers (acceptance, demand, etc.).

Consolidation stage

In this stage, the reorientation of a broad variety of assets cumulates and ultimately leads to a broader shift of regional structures. New activities are increasingly replacing old ones, thereby revealing assets no longer needed or unable to reorient.

More and more actors depart from pre-transformation activities. Eventually reaching the necessary critical mass marks an important point of discontinuity (Simmie 2012; Witt 1997). Reinforcing effects, i.e. increasing returns and positive externalities, gain further momentum. In this phase firms commercialise the new knowledge (Simmie, Sternberg, and Carpenter 2014) and abandon old structures. Not only firms but also the majority of system level actors are focusing on transformation activities and new practices.

The belief formation in the consolidation stage is ultimately resulting in a '*collective […] understanding of what might be at stake*' (Sotarauta and Mustikkamäki 2015, 353). Formation of joint visions and widely shared expectations are believed to intensify substantially in the consolidation phase. This can be expected to influence asset modification processes. The creation of novel and the reorientation of existing assets might still matter but these processes do not represent the entire picture: For the process towards path transformation to ultimately consolidate, *destruction of old constraining assets* and destabilisation of structures suppressing change (Kivimaa and Kern 2016) is necessary. Destruction is particularly relevant in later phases when alternative innovations have already gained momentum (Kivimaa and Kern 2016). Accordingly, firm-level and system-level actors alike are believed to intensify their efforts to remove constraining structures. Activities aiming at the destruction of assets are interlinked with the aforementioned creation of new and redeployment of existing assets, as they are presumably mutually reinforcing each other. This leads to a further adaptation of regional structures, which facilitate new activities and positive lock-in effects (Isaksen and Trippl 2016; Martin and Sunley 2006). The majority of regional assets are reoriented towards the new activities. In the consolidation phase the 'old rules of the game' are disregarded or adopted and the new ones are aligned and institutionalised.

Destroying, altering or de-aligning constraining assets that are strongly oriented to the old 'way of doing things' does not come without frictions. For firm-level actors it can be an expensive procedure due to sunk costs. Closures of those unable to adapt are likely to be observed. There are also obstacles to disruptive activities by system-level actors such as incumbents' interests, strong networks and rigid formal and informal institutions. Destructing constraining assets is often politically controversial (Kivimaa and Kern 2016). Therefore, the challenges in this stage

are often intra-path or intra-regional in nature. Dismantling old structures requires disruptive activities by actors from different domains[5].

To summarise, our analytical framework unravels radical 'on path' transformations by distinguishing between three stages of development, each of them coming with specific conditions ('past and future') that drive actors' agency and result in different processes of asset modification.

4 Empirical Case: Self-driving cars in West Sweden

To illustrate the conceptual arguments brought forward, and to provide additional insights into the stages of path transformation, we apply our conceptual framework to the empirical case of the automotive industry in West Sweden, which is currently undergoing disruptive changes due to the advent of self-driving cars. In other words, we use a case study methodology to complement the conceptual discussion, identifying a 'paradigmatic case' (Flyvbjerg 2006) of path transformation that serves to illustrate, and potentially challenge, the assumptions made in the conceptual discussion.

The data collection took place in two steps. First, a document study was performed, in which material such as newspaper articles, newsletters, existing reports, PR material, financial information, legal documents, policy documents and video material were reviewed. The document study served as a starting point for the narrative explored in the interviews, and as a way to identify relevant interview partners. Second, semi-structured interviews with key actors were conducted. In total, 23 respondents were interviewed between March 2017 and May 2018. All interviews were transcribed and coded, using categories derived from the analytical framework (Saldaña 2015). Interviews were conducted until a state of (albeit temporally contingent) 'data saturation' (Glaser and Strauss 2017) had been reached, that is, when no or few additional insights were gained by additional interviews. Previous studies of path development have highlighted the potential downsides of studying processes in hindsight,

[5] Focusing on the policy domain, Kivimaa and Kern (2016) identify four ways to destabilise existing systems, namely control policies (e.g. taxes and regulations), significant changes in regime rules (major changes in legislation), reduced support for dominant regime technologies (e.g. withdrawing subsidies) and changes in social networks through replacement of key actors (e.g. in policy advisory councils).

when outcomes have been materialised (Steen 2016). By studying an ongoing process, we aim to provide nuances to the complexities involved in path transformation, being aware of the difficulties involved with identifying critical events and narratives as they are happening.

The roots of the automotive industry in West Sweden range back to the beginning of the 20th century. Today the region is the home of firms from all parts of the value chain, ranging from OEMs such as Volvo Cars and Volvo AB (trucks), to global suppliers such as Autoliv, a range of smaller suppliers, and automotive technology firms and consultants. The automotive industry is supported by a strong regional innovation system, endowed with strong knowledge provision organisations such as Chalmers University, innovation support organisations and other intermediaries. The automotive industry in West Sweden is well known for its competence in safety technology. From the introduction of three-point safety belts in the 1960s, to the invention of side-impact airbags by Autoliv in the early 1990s, safety technology has been one of the industry's most important competitive edges. During the beginning of the 2000s, the regional innovation system became geared towards the development of technologically sophisticated features intended to help avoiding accidents rather than just reducing the damage when accidents occur. The shift of focus from 'passive' to 'active' safety features came with major changes to the institutional and organisational set-up of the regional innovation system, featured in previous studies (James et al. 2016). In 2009, the global technology company Google announced that they would establish a unit to develop and test self-driving cars. In our empirical material, this has been highlighted as the 'global trigger' for path transformation in the car industry. In the following sections, we outline how this process has unfolded over time in the automotive industry of West Sweden.

4.1 Initiation stage

The first signs of path transformation in West Sweden that could be discerned in the empirical material are statements by Volvo executives in newspaper articles about SDCs and the Google project, highlighting the regional asset base as particularly favourable in terms of the focus on 'active safety' technology prevailing in the region. In early media coverage, Volvo Cars executives made several statements which aimed at downplaying the radicalness of what Google had recently introduced as 'SDC technology', highlighting its relation to R&D already going on in West Sweden. For example, the appointed 'technical leader for active safety functions' at Volvo Cars expressed in a press release from 2009 that:

'[some autonomous driving features] require no hocus-pocus technology […]. Instead, the focus is on adapting existing technology.' (SP 2009).

The early initiation stage was characterised by system-level agency engaging in sense-making and vision development. A key task for regional actors was to 'translate' visions of SDCs prevailing in the media to expectations about future development that would fit the regional setting. The public sector had already for some time been discussing alternative solutions to the future of mobility. They quickly adopted the idea of SDCs and, together with actors from the automotive industry, shaped the development of visions and expectations. Both private and public actors pursued a broad strategy for introducing ideas for suggestible applications of autonomous technology, including both plans to turn existing safety technology into autonomous features, and to create visions for how future technological development could unfold. It is possible to observe the development of what could be seen as a type of 'catch-all' strategy, in which a majority of the potential benefits of SDCs are being targeted by actors' activities, with the intention of demonstrating the possible benefits without having to take on the risks associated with uncertainty. At the core of these efforts was the establishment of the 'Drive Me' consortium, initiated by Volvo Cars and initially involving the Swedish Transport Agency, the Swedish Transport Administration, the City of Gothenburg and Lindholmen Science Park (a regional support organisation).

In terms of asset modification, SDC activities in the initiation stage reflected a realignment of existing technology towards autonomous driving, rather than a divergence from the existing technological knowledge base. During the very early stage, it is even possible to label SDC technology as a continuation of existing active safety development. As one interview partner put it:

'I would say that it is a natural continuation of previous activities. It is not something that just suddenly comes from nowhere… […] We did the move from passive to active safety, this was a shift. Now, it has exploded in terms of application […] but I still see it as a natural continuation.' (Interview)

With respect to technological assets, it was thus a matter of reusing and recombining existing assets and 'packaging' active safety technology in SDC visions rather than creating entirely

new ones. This process was backed by the strong support system centred around active safety technology. In terms of missing assets, early activities targeted other dimensions than technological knowledge. Examples include the creation of novel knowledge about user behaviour, involving researchers active in disciplines such as ethnography and interaction design. Actors also engaged in demonstration activities intended to increase the legitimacy of SDCs. However, in interviews with firm representatives, it was expressed that organisational structures and established ways of working prevented incumbents from engaging in more experimental activities, which required quick decisions and more iterative, agile, development processes. Even though SDC activities were performed by incumbent actors, the regional asset base, for example in terms of firm-based competences and other industrial assets, supported these activities only when they did not depart too far from the active safety segment of the industry.

In other words, it is possible to observe a discrepancy between vision development and asset modification in the initial stage of path transformation. Asset modification focused on the re-deployment of existing assets, with the creation of new entirely new assets playing a somewhat less important role. Research efforts within the active safety segment of the industry were 're-branded' as SDC activities. Creation of new assets did thus not unfold at the same pace as the development of visions. Emerging visions were hardly reflected in the asset modification processes observed early on.

4.2 Acceleration stage

One of the first signs of the path transformation processes gaining momentum was that a broader range of actors started to become involved. From initially taking place within the incumbent firms in the region, both small existing firms and newcomers now started to engage in SDC activities. Our empirical material suggests that opportunities were starting to become visible among regional actors, fuelled by the intense vision development that took place during the initiation stage. Such opportunities were also becoming increasingly 'within reach' of actors in West Sweden due to changes to the regional asset base, both in terms of newly created assets and the ongoing process of re-deploying existing ones.

For example, existing technology firms, both active in the automotive industry and in other regional industries such as IT, started to consider SDCs as a future core area and initiated

international collaborations to strengthen their competences within the field. This took place in parallel to the emergence of entirely new actors dedicated to SDC development. Partly in response to the need for more agile and fast-moving development processes, Volvo Cars and Autoliv announced that they would transfer their software development in active safety to a new joint venture, a spin-off named Zenuity. The new firm was operational in 2017 and is the 'flagship' of autonomous technology and SDC development in the two incumbent firms' portfolios. Other examples of spin-offs include Venoeer, a subsidiary of Autoliv concerned with developing advanced electronics for active safety and autonomous driving. In interviews with Volvo Cars and Zenuity, it has been stated that the idea behind spin-off processes is to create a stronger SDC focus in order to accelerate development of SDC-specific technology.

Furthermore, new actors entered the Drive Me consortium. Chalmers University of Technology and Autoliv both joined during the second half of 2015, two years after the project was initiated. Also, collaborations with and between public actors intensified. At the local level, the city of Gothenburg was involved in the creation of 'autonomous driving zones' and signed agreements with Volvo Cars to enable SDC parking. This is one of several examples of how the public sector became increasingly involved in system-level agency during the acceleration stage. It reflected an increased interest in what SDCs can mean for the city and the region, both in terms of potentials for economic development and in terms of providing opportunities and challenges for mobility systems and spatial planning. Our empirical analysis shows that a collective understanding about the importance of SDCs for the future of West Sweden's automotive industry was forming among regional actors.

In summary, a new way of thinking about SDC technology was emerging, signalling a shift from SDCs as being part of the active safety segment of the automotive industry towards becoming its own field with a number of defining features. Fuelled by this increased divergence between the existing regional asset base, and visions and expectations about the future of the industry, asset modification processes intensified during the acceleration stage. In broad terms, automotive actors went from reapplying existing active safety technology in the initiation stage, to developing new dedicated SDC technology in the acceleration stage. One executive from Zenuity stated that:

'We are continuously updating a gap-list describing what is missing in order to execute the strategy that we have [towards unsupervised driving]' (Interview)

This involves both the creation of entirely new assets and the 'de-locking' of assets aligned to existing paths. One prominent example of the latter is how Volvo Cars and Autoliv transferred all patents and other intellectual property rights related to active safety software to Zenuity, in order for the new firm to be able to use them in new ways than would have been possible within incumbent structures. In one of our interviews with Zenuity, it was expressed that the separation from the incumbent firms gave them long-term stability that would not have been possible if being organised as a joint project within existing structures. Similarly, inter-path interactions, primarily between the regional automotive industry and the IT industry, are also indications of de-locking processes of regional assets and redirecting them to SDC activities. This is illustrated by intensified interactions between IT firms and automotive firms, both in terms of collaborations in projects and in terms of labour mobility from IT firms to the automotive industry.

During the acceleration stage, the formation of a supportive organisational and institutional environment facilitating the formation of complementary assets became visible. Examples of agency targeting the system level includes the development of education programmes and research projects designed to boost SDC development, and activities targeting the dismantling of old standards and modes of working in the automotive industry, which started to become increasingly obsolete. Furthermore, firm actors engaged in institutional entrepreneurship, most notably through activities seeking to adapt regulations for SDC trials. For example, Volvo Cars provided inputs to an investigation at the national level, aimed at mapping the legal preconditions for automated transport in broad terms. They also took part in discussions with the Swedish Transport Agency and the Swedish Transport Administration, both within and outside of the Drive Me project. After intense lobbying efforts from regional actors and several rounds of discussions, a special national regulation for SDC trials and routines for issuing permits was in place at the end of 2017 (see also Miörner 2018).

The empirical analysis also shows that some of the challenges in the acceleration stage, such as legislative barriers, were successfully targeted by efforts of system agency. Others made their appearance with the intensification of activities. For example, the increased contact surfaces between the automotive industry and the IT industry did not only lead to opportunities for collaboration, but also a competition for resources such as skilled labour, regional funding and political attention. One interview expressed that:

'For a while, a lot of people left [an IT firm located in the region] … for us. They were almost angry at us.' (Interview with automotive firm representative)

It is also possible to identify contested visions when it comes to defining the routes and direction of SDC development. For example, when the city of Gothenburg was working with long-term visions and planning perspectives involving SDCs, they deviated from the 'car ownership norm' prevailing in the automotive industry, and anchored their visions in possible trajectories in which new mobility services are introduced alongside autonomous technology. The existence of contested visions has not materialised into actual conflicts among actors, but it is possible to observe a clear divide. Many system level actors perceive autonomous driving technology as an alternative to private car ownership, whilst automotive firms see it mainly as an addition to the existing car-based mobility paradigm. As one interviewee, an individual with long experience of working in the automotive industry, put it:

'there are people [in the automotive industry] who do not think there's any reason whatsoever to limit the accessibility of autonomous driving technology, but others highlight the need to limit the use to shared cars, in particular in city centres.' (Interview)

Finally, whilst asset modification processes did indeed target the re-orientation and de-locking of existing assets to a greater extent in the acceleration than in the initiation stage, actors acknowledged the need to develop entirely new assets. However, our interviews highlighted the fact that whilst spin-off processes from the large incumbent firms to some extent can help them become more flexible, they do not fully compensate for what was perceived as a 'weak entrepreneurial climate' (Interview) in the region, preventing more 'radical' asset creation processes to get traction. Interview partners in the automotive industry acknowledged the need for engaging more with small actors but lacked the means and experience to do so.

4.3 Consolidation stage

The 'broad commercialisation' of autonomous technology expected during the consolidation stage is yet to be observed in West Sweden (and other automotive regions across the world). The commercialisation of new SDC technology is still taking place within the active safety segment of the industry, illustrating an interesting case of how new, potentially radical,

technology is introduced in ‘old’ market segments while waiting for new market possibilities to materialise. In other words, the industrial path transformation process is ‘running ahead’ of the broader societal shift, as it is possible to observe signs of consolidation in terms of actors, visions and assets active in the regional path.

The number of actors involved in SDC activities has been growing continuously throughout the path transformation process and now represents a critical mass of actors. Several dedicated SDC technology firms have emerged in the region, through spin-off and start-up processes and relocation from other regions. In addition, a number of firms in other industries, most notably the IT industry, have diversified into SDC technology and inter-path acquisitions have taken place. This has been complemented by a continued engagement by actors from the public sector and regional support organisations.

When it comes to visions, efforts concerned with belief formation in the acceleration stage have consolidated to a shared understanding of SDCs as the future of the automotive industry in West Sweden. This is manifested in different ways. Autonomous driving has become an integral part of urban planning policies in Gothenburg and regional strategies have started to refer to West Sweden as a ‘self-driving region’. Furthermore, the evidence suggests a broad consensus among public actors about the importance of supporting SDC development. Finally, regional firms operating in different industries are signalling their interest in different aspects of autonomous technology through investments and acquisitions. However, our study shows that whilst there is a collective understanding about the importance of SDCs for the future of the regional industry, there is still no established consensus when it comes to the question of how the new technology will materialise and what it means for society. The contested visions outlined in the acceleration stage still prevail and actors base their decisions based on different, sometimes incompatible, logics. An illustrative example derived from our findings is how the vision of reaching the more or less completely self-driving car is highlighted in the media and in discussions with public actors, whilst goals and strategies internal to the automotive firms are more oriented towards increasing the functionality of their existing cars, adding layers of self-driving features that will support the driver and car owner.

Some implications of these contradictions can be observed in the regional asset base. Asset modification processes continue to target the re-deployment and re-orientation of existing regional assets, in combination with the creation of new assets. The destruction of old assets is

however not as prominent as would be expected from the theoretical discussion. In some areas, existing assets still form barriers to full-scale transformation and whilst the empirical analysis shows early signs of how actors are acknowledging the need to target the destruction of such assets, things are yet to take off on a broader scale. For example, several interview partners have highlighted how the main 'product' of the automotive industry is shifting from 'cars' towards 'software'. Our empirical analysis indicates that there are still institutional assets preserving 'old ways of doing things' and constraining this shift. A case in point are old hierarchies and modes of working in the incumbent automotive firms. For example, our interview partners highlighted how platform-based development models among incumbent automotive firms need to shift towards more agile processes, inspired by how development projects are run in the software industry.

The most prominent signs of consolidation are instead found in the regional support structures emerging around SDC development in West Sweden. Throughout the acceleration stage, a number of support elements were introduced to deal with some of the challenges identified. Examples include organisations and initiatives promoting the attraction of extra-regional assets (like global start-ups and talent), as well as new research centres focused on technologies particularly important for SDC development such as artificial intelligence and vehicle electronics. Also in terms of institutional endowments, the special regulations for SDC trials have been 'tried out' in practice. In 2018, Zenuity obtained a permit which allowed only trials with 'hands on the wheel' and banned automatic lane switching, followed by a permit with fewer restrictions in January 2019. The latest permit is, according to statements by Zenuity in the media, sufficient to perform the planned trials. To a major Swedish newspaper, the CEO of Zenuity said that:

'With the new permit we are able to perform real tests. We are happy to be able to do the tests in Sweden.' (Svenska Dagbladet 2019)

To summarise, as of summer 2019, the path transformation process leading towards SDCs in West Sweden is still ongoing; some aspects have been consolidated whilst others remain fragmented and contested.

5 Conclusions

In recent years there has been a shift of attention towards the creation of new industries in the field of EEG. In this paper we highlight the need to take radical 'on-path' transformations into account more explicitly. We propose a stage model of path transformation, distinguishing between three phases, that is, an initiation, acceleration and consolidation stage. Each of the phases is believed to come with quite specific characteristics, pointing to the need to examine industrial restructuring from a process perspective.

Based on a systemic view on regional structural change, four interdependent key dimensions of change have been identified. Accordingly, (i) actors of different domains – influenced by (ii) historically grown structures and (iii) future prospects – are engaging in (iv) deliberate and purposeful actions to alter the regional asset base. We bring forward the argument that different asset modification processes, namely transplantation or creation of new assets, redeployment of existing assets and destruction of constraining assets, differ in their relative importance depending on the stage of development. Creation and/or transplantation of assets are expected to prevail in the initiation stage, while redeployment of existing assets is assumed to be more dominant in the acceleration stage. Finally, we expect that destruction of constraining assets may play a vital role during the consolidation stage of path transformation.

Applying the conceptual model to the empirical case of West Sweden's automotive industry has provided additional insights and revealed open questions. First, the case study confirms the crucial yet often overlooked 'role of the future' for path development processes (Hassink, Isaksen, and Trippl 2019). This paper therefore makes a strong case for incorporating the dimension of vision building and collective belief formation into analyses of innovation-based path development. Visions are a subject to continuous re-evaluation and development, yet they are not random. They reflect previous experiences, current processes and refer to actors' assessment of the probability of certain scenarios playing out in a certain way (Steen 2016). As our empirical analysis has shown, system level actors can contribute to providing a clear vision and attitude towards the future (in our empirical case for instance through the establishment of the Drive Me project). Their agenda setting activities might therefore serve as a guide through the long-term, complex processes of path transformation, especially in early phases that are characterised by great uncertainty (Mazzucato 2016).

Second, our empirical analysis has also revealed some deviations from the development patterns proposed in the conceptual framework. Most notably, asset creation has not been that important in the initiation stage due to the already mature asset base in the active safety segment.

Our conceptualisation of path transformation provides a broad framework to capture the course of industrial re-orientation. One has to acknowledge that the underlying processes might differ substantially, depending on the industrial and regional context under consideration. As paths are complex entities, we do not hold deterministic claims. Our conceptual model rather points to ideal-type processes. As with similar conceptualisations, it is hardly possible to define clear-cut thresholds to identify transitions from one phase to another (Markard 2018).

Third and in line with other recent contributions (Miörner and Trippl 2018; Tödtling and Trippl 2013), the analysis showcases that fundamental change of mature industries requires alterations of the surrounding and strongly aligned innovation system in place. Accordingly, the transformation of an industrial path involves processes of destruction or de-alignment of constraining local assets (Trippl et al. 2019). As this is expected to take place in later stages of development, large-scale destabilizing endeavours are yet to be observed in West Sweden's automotive industry. Thus, further research investigating the nature of asset destruction and de-alignment is required. Key questions may include: What role does power play in this regard? What is the role of incumbents in facilitating or preventing such processes of destruction or de-alignment? How can policies orchestrate and accelerate asset destruction (Kivimaa and Kern 2016) at different spatial scales?

Forth, the empirical case proves the necessity to pay due attention to inter-path relations (Frangenheim et al., 2018). While it is the automotive industry that is transforming, the process is strongly facilitated by drawing on assets (like the scarce asset 'skilled labour' but also non-scarce assets like working routines) from the IT industry within the region. The transformation of the automotive industry therefore leads to both collaboration and competition between the two paths and creates strong path interdependences: activities in one industry affect but also are affected by activities in the other industry. More research is required to unravel these interdependencies (Hassink, Isaksen, and Trippl 2019).

Lastly, applying the analytical framework to other regions and industries and carrying out cross-regional comparisons of similar paths in different spatial settings settings would be highly instructive and could lead to a further refinement of the conceptual arguments proposed in this paper.

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