Resources Policy 109 (2025) 105702

Contents lists available at ScienceDirect

Resources Policy

journal homepage: www.elsevier.com/locate/resourpol

Igniting sparks for the transition of a coal mining region: The role of firm- and system-level agency to innovate, diversify and create new growth paths in a regional innovation system

Jan Henrik Gruenhagen [a,*], Janice Terrill [b], Stephen Cox [b]

[a] Transdisciplinary School, University of Technology Sydney, Ultimo, New South Wales, Australia
[b] Faculty of Business & Law, Queensland University of Technology, Brisbane, Queensland, Australia

ARTICLE INFO

Keywords:
Coal transition
New path development
Regional innovation systems
Firm- and system-level agency
Diversification
Lock-in

ABSTRACT

Global transitions to a low-emissions future pose structural, economic and societal challenges for regions heavily dependent on coal mining. Regional and firm-level inertia with a lack of diversification activities and an absence of innovation risks a trajectory of path dependence and negative lock-in. Integrating regional innovation systems and evolutionary economic geography perspectives, this study analyses a regional innovation system heavily dependent on the coal mining industry during a period of relative stability before a potential period of industrial and regional decline. Relying on a case study methodology, we illustrate innovation implicative dynamics of both the firm and system that reinforce or challenge the path dependence of the Mackay region in Queensland, Australia. By differentiating between firm- and broader system-level agency, we highlight that firm-level diversification and innovation activities prevail over system-level agency, so that it is the agency of individual firm actors that shows the potential to create new growth paths on the system level. We also illustrate a lack of pronounced system-level agency, suggesting the prevalence of obstacles for a regional transition away from coal mining. Our findings emphasise the importance of the role of visions and entrepreneurial orientation among firms to lay the groundwork for regional diversification and driving change.

1. Introduction

Mitigating the negative effects of climate change necessitates transitioning away from the reliance on fossil fuels, including coal (Feng et al., 2023; Fleming-Muñoz et al., 2020). As several countries have committed to targets to reduce emissions and to eventually achieve net-zero, climate-driven action impacts the current economic structure through transitions occurring (Fleming-Muñoz et al., 2020; Tol, 2018). These actions pose challenges for regional economies whose industry structure and associated employment market are heavily reliant on fossil fuels, threatening to disrupt economic and social well-being (Cała et al., 2021; Feng et al., 2023; Fleming-Muñoz et al., 2020). In order to avoid a decay of regional economic power and job markets, regions need to adapt to changing market and policy conditions and, in the long-term, reduce reliance on fossil fuels in their economic profile to enable transformative regional development (Chlebna et al., 2023; Zhou et al., 2022).

Regions threatened by industrial decline, however, differ in their ability to diversify into new growth paths (Boschma and Frenken, 2006). Patterns of regional development and economic activities are at risk of becoming path-dependent, with historical events and contingencies reinforcing processes and mechanisms affecting pathways of development and preventing alternative growth paths (Martin and Sunley, 2006). Such regions suffer from a 'lock-in', with economic activities and structures fixated on a particular trajectory, based on the sequence of past events and contingencies, as well as on institutional, social and cultural norms and behaviours (Isaksen, 2001; Martin and Sunley, 2006). Regions whose development path is characterised by the reliance on a natural resource, such as coal, are prone to path dependence, with institutions, infrastructure, local assets, and industry specialisations oriented towards this industry (Martin and Sunley, 2006; Sun et al., 2024). As such, an industry regime is dominant and difficult to change due to a common knowledge base, institutions supporting the regime and interests nested with the regime (Boschma et al., 2017).

Therefore, a key challenge to counteract the decline of a regional innovation system is to foster the development of new paths beyond

* Corresponding author. UTS Building 7, Level 4 67 Thomas St, Ultimo, NSW 2007 Australia.
E-mail address: JanHenrik.Gruenhagen@uts.edu.au (J.H. Gruenhagen).

https://doi.org/10.1016/j.resourpol.2025.105702
Received 16 March 2025; Received in revised form 31 July 2025; Accepted 4 August 2025
Available online 11 August 2025

existing – often 'locked-in' – trajectories (Isaksen et al., 2018). For new paths to be created and developed, new industries and economic activities need to emerge and grow in a region (MacKinnon et al., 2019). Such developments need to be sufficiently different to existing economic initiatives to avoid limiting activities to incremental innovations that would not foster the emergence of new paths (Isaksen et al., 2018). Small changes are unlikely to overcome lock-in effects and hence, do not substantially shift a regional innovation system's trajectory (Tödtling and Trippl, 2013). Since a regional innovation system constitutes firms, organisations and institutions regularly engaging in interchange, learning and innovation, and thereby influencing the economy of a region, changes to a regional economy are induced by local firms (Asheim and Gertler, 2006; Cooke et al., 1997; Neffke et al., 2018). At the same time, the region creates the context for development paths of the firms it hosts (Neffke et al., 2018). As such, the emergence of new growth paths is a two-way interaction.

To understand the diversification of a region and the emergence of new growth paths, it is therefore necessary to apply a multi-level perspective, considering behaviours of firms that are part of a system at the micro-level, as well as non-firm system-level actions and structures shaping innovation and economic profile of a region. Firms, as important actors on the micro level, are part of the endogenous capabilities of a regional innovation system (Cooke et al., 1997; Isaksen et al., 2018). From an evolutionary economic geography perspective, they mobilise and anchor resources contributing to the foundational work for forming new growth paths (Binz et al., 2016). Research on regional innovations systems, however, suffers from a static view primarily focussing on structures and networks, with limited consideration of firms' agency, while evolutionary economic geography has understood new path development primarily as firm-driven, without a profound consideration of other actors such as institutions, policy and state (Hassink et al., 2019; Tödtling and Trippl, 2013).

Integrating regional innovation systems and evolutionary economic geography perspectives and the concept of agency, the objective of this study is to analyse a regional innovation system heavily dependent on the coal mining industry in the context of global transitions to a low-emissions future. Specifically, we aim to investigate firm- and system-level diversification activities and visions as potential sparks for new path development. We conceptualise diversification activities as manifestations of agency, both on the firm and system level, whereby firms are part of the broader system. Firm-level agency encompasses influences within a firm or organisation, such as entrepreneurial innovation and diversification activities within a firm which may also have the potential to initiate change on the system level. System-level agency incorporates institutional actions, policies and collaborative activities among multiple firm and non-firm actors to transform a system and support new paths (Hassink et al., 2019; Isaksen et al., 2019). In doing so, we attempt to uncover opportunities and challenges for the renewal of a region to avoid negative lock-in. In making a distinction between firm and system agency, we do not imply that firms are separate from the system in which they operate. In line with dominant innovation systems perspectives (see, for example, Bergek et al., 2008; Geels, 2011) we locate firms as interacting with a range of other actors, including other firms and institutional actors, operating within sets of formal and informal institutions. We particularly focus on firms as a major source of innovation and path development. Our study context is Mackay in Queensland, Australia; a region heavily dependent on the coal mining industry, making it vulnerable to a decline of the sector (Burke et al., 2019; Ivanova, 2014). In particular, Mackay is home to a highly developed and concentrated mining supply industry as well as to one of the major ports in Australia for exporting coal (de Villiers Scheepers et al., 2021; Valle de Souza et al., 2018).

Our study contributes to the literature on regional innovation systems and evolutionary economic geography by applying an integrated framework to substantiate firm- and system-level agency, accounting for both structure and dynamics of a regional economy. We also demonstrate that functional, political and cognitive lock-ins do not only occur on a regional level but also on a firm level, albeit with different magnitudes. Third, by analysing a region not retrospectively after industrial and regional decline have occurred but during a period of relative stability, we highlight the agency of firm actors to lay the groundwork for diversification and driving change in a system, thus exhibiting nascent potential to reduce regional lock-in. The paper proceeds as follows. In the next section, we will establish our analytical framework based on reviewing the literature on new path development, agency, different types of regional innovation systems, and the transformation of mining regions. In doing so, we will specifically focus on the role of actor and system level agency in developing new growth paths for a region as a foundation for transformations. We will then describe the methods we used to analyse the case of Mackay as a region heavily dependent on the coal mining industry. Following, we will report the insights we have gathered from the case study analysis and discuss their implications.

2. Literature review

The conceptual framework for our study draws on the literatures on new path development, regional innovation systems, and agency. New path development is a key concept in evolutionary economic geography to explain how new economic activities emerge in a region, contributing to structural change and the industrial transformation of a region (Boschma et al., 2017; Hassink et al., 2019; Isaksen et al., 2018). The concept of the development of new growth paths, however, has been criticised for focussing too much on regionally anchored firms as driving forces for new path development, overlooking other actors such as policy makers, universities and non-local firms (Hassink et al., 2019). Although firms are a key source of innovation (Cantwell and Fai, 1999), they are not they only source, and they do not successfully innovate completely independently of their regional context (Asheim et al., 2016). On the other hand, while the regional innovation systems literature acknowledges the structure and networks of a broad set of actors in a region, it has been criticised for an overly static view, often neglecting dynamics in the system as well as firms as important actors of change (Gertler, 2010; Tödtling and Trippl, 2013). Understanding the dynamics of a regional innovation system requires a focus on the agency of actors (Tödtling and Trippl, 2013). Agency can result in the emergence of new growth paths and change the structure of a regional innovation system (Grillitsch and Sotarauta, 2020; Isaksen et al., 2019). Following prior studies, we therefore integrate these literature streams to better understand agentic actions across multiple levels that could manifest in new path development in a regional innovation system heavily reliant on coal mining.

2.1. Path dependence and firm diversification activities as avenues for new path development

The concepts of 'path dependence' and 'lock-in' have become popular perspectives to explain regional development trajectories and associated economic activities (Binz et al., 2016; Garud and Karnoe, 2013; Isaksen and Trippl, 2016; Martin and Simmie, 2008; Martin and Sunley, 2006). Development pathways and structures of a region can be 'locked in' by self-reinforcing mechanisms and processes based on historically contingent events (Martin and Sunley, 2006). Path dependence incorporates "purposeful human agency as well as the structural preconditions and contextual influences that shape its emergence and operation" (Martin and Sunley, 2006, p. 41) As such, a region's innovation and economic activities are shaped by a region's pre-existing industrial and institutional structures, therefore maintaining its existing industrial setup in the long-term (Isaksen and Trippl, 2016). Specialisations and innovation activities of firms, a common knowledge base, infrastructure, assets and institutions contribute to path dependence, supporting a dominant industrial regime within a region

(Boschma et al., 2017; Martin and Sunley, 2006; Sun et al., 2024). Regions whose industrial path relies on natural resources, such as coal, tend to be path-dependent (Martin and Sunley, 2006; Sun et al., 2024).

'Lock-ins' associated with dependence on a specific path, however, are not necessarily negative. A region's industry specialising in a sector and following a specific path can stimulate economic growth and therefore exhibit a positive 'lock-in' (Martin and Sunley, 2006). However, when growth dynamics diminish – such as through inertia and established routines, or exogenous shocks – path dependence can turn into a weakness and a negative 'lock-in' (Martin and Simmie, 2008; Martin and Sunley, 2006). Thereby, local industries and, hence, regions may decline economically, impeding renewal processes due to these negative 'lock-in' effects (Grabher, 1993; Hassink, 2010a). 'Lock-ins' of regional development are related to an interplay of functional, cognitive and political 'lock-ins' (Grabher, 1993; Hassink, 2007). Functional 'lock-ins' relate to stable and dense linkages between local firms blocking alternative pathways, cognitive 'lock-ins' represent a common worldview and mindset preventing the emergence of new ideas, whereby political 'lock-ins' refer to close relationships between political elites and industry maintaining industrial structures (Grabher, 1993). While external factors or exogenous shocks – such as the growth of competing industries or, as an example, the phase-out of coal – can push locked-in regions to renew, as an opposite effect, it can turn them into a downwards spiral solidifying negative 'lock-ins' (Martin and Sunley, 2006). However, path dependence is also place-dependent, explaining variations between different regions and the magnitude and direction of 'lock-in' effects (Martin and Sunley, 2006).

For regions to escape negative 'lock-ins' from path dependence, new growth paths need to be developed (Martin et al., 2019). Path creation represents "the emergence and growth of new industries and economic activities in a region" (MacKinnon et al., 2019, p. 144). This terminology, however, has not been unanimously agreed upon in the literature, with some scholars using 'path creation' as an umbrella term, and others using 'new path development' as a generic term for different types of new growth paths (Hassink et al., 2019). In the latter perspective, path creation manifests the most substantial form of change (Isaksen et al., 2018), whereby new path development, as an umbrella term, can incorporate different types and mechanisms of change. Following this perspective, Isaksen et al. (2018) categorise regional industrial path development into five forms: Path extension involves incremental innovation in existing industries that support the continuation of a path. Path modernisation is based on new technologies or innovations that change the pre-existing industrial path into new directions. Path branching refers to a new industry being developed based on knowledge and capabilities that exist in related industries. Path importation involves the importation of industries that are established elsewhere but are new to the region. Path creation reflects the "emergence and growth of entirely new industries based on radically new technologies and scientific discoveries or as an outcome of search processes for new business models, user-driven innovation and social innovation" (Isaksen et al., 2018, p. 224). These different types of new path development are related to the extent of regional structural change (Isaksen et al., 2018).

New growth paths can develop through existing knowledge and diversification activities within pre-existing structures and routines of a region's industry and organisations (Boschma and Frenken, 2011). However, path development processes are argued to not only rely on pre-existing structures and routines, but also on the process by which resources are mobilised for industry formation based on demand and market conditions (Binz et al., 2016). These input factors can be internal or external to the region (Binz et al., 2016).

2.2. Agency in new path development

Avoiding 'lock-ins' of regional development requires the emergence of new growth paths and, related to this, structural change. Such changes can be initiated through the agency of individuals, groups and organisations, whereby agency may be linked to structural change (Sotarauta and Grillitsch, 2023). While firms with their innovation and entrepreneurial activities are an essential agent for the development of new growth paths (Grillitsch and Sotarauta, 2020), processes and dynamics coevolve with non-firm actors, such as that firms require supportive institutional actors (Binz et al., 2016; Isaksen et al., 2018). Firms as agents of innovation are contextualised within specific regions, industries and institutions, but exposed to broader – such as national – institutional environments as well as knowledge, assets and networks that span regional boundaries (Hassink et al., 2019; Isaksen et al., 2018; Parrilli et al., 2016). As such, innovation and diversification activities of firms are a basis for new path development but are subject to interactions with system-level actors and institutions (Grillitsch and Sotarauta, 2020), whereby firms are likewise an integral part of the system.

It is therefore a range of actors across multiple levels – and their interplay – that have the agency to change, or maintain, the path of a region (Baumgartinger-Seiringer, 2022; Martin, 2013). These actors engage in actions or interventions that may have a particular effect – that is, they are agentic (Isaksen et al., 2019). Agency can occur both on the firm- and system-level, and their combination can affect new path development and transformations of a region (Isaksen et al., 2019).[1] Firm-level agency centres on influences within a firm or organisation, such as initiating innovative and entrepreneurial activities within a firm, which may have the potential to create new growth paths (Hassink et al., 2019; Isaksen et al., 2019). System-level agency incorporates agency outside of organisational borders. This includes, for example, collaborations among firms and research institutes developing new knowledge that transcends organisations, or policy initiatives that have the potential to change a regional structure and its innovation system, and thereby affect new path development (Benner, 2024; Gong et al., 2022; Hassink et al., 2019; Isaksen et al., 2019). Specifically, system-level agency may change the regional structure for innovation, such as changes to institutions or policy instruments (Isaksen et al., 2019), but changes can also originate from within firms as part of the system.

The literature on agency in the context of new growth paths has adopted a range of conceptual notions of agency to explain the actions and interventions that may affect new path development and structural transformations (Grillitsch and Sotarauta, 2020). Grillitsch and Sotarauta (2020) argue that three, albeit interconnected, types of agency drive regional path development: Innovative entrepreneurship, institutional entrepreneurship, and place-based leadership. Innovative entrepreneurship has parallels to firm-level agency, where firms act upon entrepreneurial opportunities and innovate (Grillitsch and Sotarauta, 2020; Isaksen et al., 2019). Entrepreneurs, but also other actors or a combination thereof, engage in institutional entrepreneurship to change existing or to create new institutions (Grillitsch and Sotarauta, 2020), as such, agency on the system-level. Place-based leadership, another type of agency on the system-level, incorporates the organisation and orchestration of actors for new path development (Grillitsch and Sotarauta, 2020). Here, the construction of a shared vision for the direction of change plays an important role (Grillitsch and Sotarauta, 2020). It should be noted, though, that agency can also be oriented towards maintaining a region and its structure, and suppressing change (Baumgartinger-Seiringer, 2022; Jolly et al., 2020). Maintenance agency, as opposed to change agency, may result in a lack of new path development and regional restructuration (Baumgartinger-Seiringer, 2022).

[1] While we build upon common distinctions made in the literature between firm- and system-level, we view firms as an integral part of the system, and not separate or distinct from the system. We use this denotation to describe agency originating from within firms (as a part of the system) as opposed to agency outside of organisational boundaries.

2.3. Types of regional innovation systems

To establish the systemic context for path development and agency in path development, we now turn to regional innovation systems. The regional innovation systems perspective highlights the regional level, with its firms, organisations and institutions that together absorb and generate new knowledge, innovate and contribute to a region's economy (Asheim and Gertler, 2006; Cooke et al., 1997).

Institutional, political, cultural, and economic forces shape a region and contribute to different trajectories of a regional innovation system – therefore explaining differences across regional innovation systems (Cooke et al., 1997). The literature on regional innovation systems has categorised regions as having different types of regional innovation systems, based on structural variations and varying associated processes and dynamics (Isaksen et al., 2018; Isaksen and Trippl, 2016; Tödtling and Trippl, 2005). This allows distinguishing regions that are high-performing due to well-developed structures and dynamics from those regions that lack industrial clustering and relevant institutions, suffer from limited interactions and poor network structures, and are prone to 'lock-ins' (Tödtling and Trippl, 2005). Such differences affect the extent to which a region can develop new growth paths, and what mechanisms and dynamics are required for structural change (Isaksen and Trippl, 2016).

Building upon Isaksen and Trippl (2016) and Tödtling and Trippl (2005), Isaksen et al. (2018) distinguish between three types of regional innovation systems: Organisationally thick and diversified, organisationally thick and specialised, and organisationally thin regional innovations systems. According to this, *organisationally thick and diversified regional innovation systems* are spatially associated with metropolitan areas and technologically advanced regions (Isaksen et al., 2018). Structurally, these regions are home to a variety of industries and supported by diverse knowledge-intensive and innovation-focussed organisations, such as universities and private support organisations, with networks supporting knowledge flows (Isaksen et al., 2018). Isaksen et al. (2018) argue that this type of regional innovation system offers strong opportunities for path modernisation, branching and creation. *Organisationally thick and specialised regional innovation systems* are often associated with old industrial areas and specialised manufacturing regions, and characterised by a narrow industrial base in one or a few sectors, with organisations reinforcing this arrangement, and networks dominated by the prevailing industrial setup (Isaksen et al., 2018). These regions are prone to 'lock-ins'; the development of growth paths is often restricted to path extension and path modernisation (Isaksen et al., 2018). Lastly, *organisationally thin regional innovation systems* are found in regions without strong industrial clusters, little knowledge exchange and limited support organisations, which is often found in regions with SMEs in traditional and resource-based industries, sometimes in combination with larger externally owned plants (Isaksen et al., 2018). These regions face considerable challenges with the development of new growth paths (Isaksen et al., 2018).

2.4. Transformations of coal mining regions

Empirically, several studies have investigated the transformation of regions historically reliant on coal mining. For a systematic review, Diluiso et al. (2021) identified 194 publications on coal transitions in 44 countries, suggesting that the main challenges for coal-dependent regions relate to structural change, with policy makers primarily relying on regulatory instruments to drive transitions. In terms of regional structure and development, a key challenge centres on transitions to other industries and sectors to mitigate the economic and social impact of the coal exit (Diluiso et al., 2021). Building on case studies of Germany's Ruhr region and Australia's Latrobe Valley, Coenen et al. (2018) conclude that these coal regions exhibit regional innovation system challenges similar to those faced by old industrial regions. Specifically, an industrial mono-structure fitting the coal industry, dense industry-specific actor-networks and strong institutions supporting the regime affect the transformation of such regions (Coenen et al., 2018; Matern et al., 2023). These characteristics are associated with lock-in effects, mere path-extension, weak entrepreneurial capabilities, and entrenched positions towards coal mining that impede collaboration and collective action (Coenen et al., 2018), whereby firms, communities and civil society shape the identity of a region (Alexandra, 2017). However, often the involvement of civil society in decision-making processes remains limited (Matern et al., 2023). In the case of the UK and Germany, incumbents delayed the phase-out of coal and thereby extended the path of coal mining regions, albeit to a different extent, by framing coal mining as necessary for energy security, employment and domestic competitiveness (Brauers et al., 2020). Modelling suggests that an earlier phase-out is associated with negative effects emerging earlier, but also with a faster recovery counteracting those effects (Oei et al., 2020b). While regions rich in natural resources such as coal are slower to seek industrial restructuring during a positive economic climate, the presence of local capabilities can increase transformation efforts (Chen et al., 2024), suggesting that innovative firms and support organisations at the regional level are important for regional transformation.

A few studies have investigated the role of agency in the diversification of mining regions. Analysing the case of a mining town in Sweden, Stihl (2022) concludes that despite diversification occurring, local mining culture and incumbents discourage entrepreneurship and change that could challenge the set path further. However, findings show that agency in the form of innovative entrepreneurship, institutional entrepreneurship and place-based leadership enabled diversification towards tourism, with some reorganisation of support structures (Stihl, 2022). In the case of a coal region in China, entrepreneurial activities did play a role for new path development, but it was primarily driven by the local state government that mobilised existing local assets (Hu, 2017). As such, the dynamic agencies were shaped by the political-institutional environment (Hu, 2017). Comparing two mining cities in China, Hu and Yang (2019) found different agentic dynamics – such as that in one region entrepreneurial agency was able to shape institutions towards new path development, whereby in the other case a self-reinforcing institutional environment was observed, limiting opportunities for new path development. These studies suggest that different types of agency at different levels affect the potential for new path development, albeit with varying magnitudes, and its absence can reinforce path extension and a lack of diversification.

3. Data and methods

The objective of this study is to investigate a regional innovation system in light of firm- and system-level diversification activities as sparks for new path development, thereby uncovering opportunities and challenges for the renewal of a region dependent on the coal industry in the context of net-zero transitions. In doing so, we employ qualitative research methods and implement a single case study design (Yin, 2009). The rationale is to study a phenomenon with its complexities in its real-life context (Yin, 2009). Our case study comprises the Mackay region in Queensland, Australia. The region's industry is heavily dependent on the resources sector which is the largest contributor to gross regional product and employment creation (Thomson, 2023). Mackay is the gateway to major coal resources and known for its highly developed and concentrated mining supply industry (de Villiers Scheepers et al., 2021; Valle de Souza et al., 2018). Treating the Mackay region as our geographically bounded case, we employed a sampling and data collection strategy to paint a rich picture of the region aligned to our research objective. As such, we aimed to understand (1) diversification activities of firms as manifestations of firm-level agency, (2) institutional actions, policies and strategies representing system-level agency, and (3) structural properties of the case under investigation.

3.1. Data collection

In line with our objective, we relied on both primary and secondary data to answer our research questions. We used both sources of data to compile our case study by analysing insights from a wide range of individual sources and informants. For the collection of primary data, we designed semi-structured interviews comprising of a series of open-ended questions to cover areas and topics of relevance (Saunders et al., 2009). Interview questions served as a guide but were adapted based on the individual informant and the flow of the conversation. This was necessary to account for variances in the firms our interviewees represent, as well as accounting for collecting data from multiple entities including firms, government, and industry organisations. The interview questions broadly focussed on innovation activities conducted by firms, perceptions of the industry and the region, interactions between different actors and institutions, and expectations and visions related to the future of the industry and the region. Interviews were conducted as part of a larger multi-year research project, of which this study was one focus area. We conducted interviews face-to-face or online via video-conferencing software between 2019 and 2022. Audio recordings of the interviews were then transcribed verbatim. In addition to primary data in the form of interviews, we also relied on a range of secondary data, including industry and government reports, grey literature, policy briefs, economic data and publications in the mainstream media. Members of the research team also attended industry events and exhibitions in the region to become immersed in the subject matter.

3.2. Sampling

Our aim was to achieve an in-depth and multi-faceted exploration of the case under investigation. This necessitated a broad coverage of relevant stakeholders in our primary data. As part of our larger research project, we therefore employed a purposive sampling strategy to identify and select participants of relevance for answering the research questions (Patton, 2022; Saunders et al., 2009). Specifically, this included focussing on firms based in the Mackay region that supply the mining industry with products or services, representatives from industry organisations that are active in the region, and government officials whose repertoire includes the region and/or industry. We identified interviewees via publicly available information (such as databases and websites) and also relied on referrals from individuals familiar with industry and region. Potential interviewees were approached via phone or email. We aimed at collating a heterogeneous sample, representing firms of different sizes, and institutions across different levels – i.e. regional, state, and federal. The final sample utilised for this study comprises of interviews with 35 informants (see Table 1).

3.3. Data analysis

Analysis of the data involved an iterative process to make sense of the substantial volume of qualitative data. Secondary data was categorised, annotated with notes, and key insights extracted. Transcripts of the interviews were inductively coded utilising both paper, pen and highlighter, and the software package NVivo 14. Interviews were read line by line and then initially coded descriptively to concisely summarise the topic of a passage of text (Saldaña, 2021). This was followed by pattern coding to identify meaningful themes in the initially coded data. Based on this, data was grouped and organised into first- and second-order themes (Auerbach and Silverstein, 2003; Saldaña, 2021). Themes were then categorised into two overarching thematic areas. Throughout the process, supporting documents with notes and structures were created to assist with data analysis. The process was highly iterative, cycling between data, literature, and established codes and themes (Srivastava and Hopwood, 2009). During multiple discussions within the research team, themes and their categorisations and descriptions were revised and refined to establish the final version. We triangulated the data between different sources as well as based on the insights obtained from immersing into industry and region to increase its validity (Guion, 2002; Yin, 2009).

Table 1
Distribution of interviewees in the sample.

Informant from	# of interviewees
Firm based in the case study region	19
Regional industry association/support organisation	4
State/National industry association	3
Regional educational institution	2
Regional/State government	5
Federal government	2

4. Case study insights

The following sub-sections summarise insights and findings from our case study analysis. First, we present an economic profile of the region constituting a canvas for the structure and dynamics of our case study. We then continue with illustrating the results of our thematic analysis of the data.

4.1. Economic profile and background

Mackay is a regional town and local government area (LGA) 950 km north of Brisbane and approximately mid-way between Brisbane and Cairns on the Queensland coast in Australia. The Mackay LGA is bounded to the west and south by Isaac LGA, where the majority of the rich coal mines of the Bowen Basin are located (Mackay Regional Council, 2023). The Peak Downs Highway is the major east-west road link connecting Mackay to the Bowen Basin coal fields, and towns and agricultural centres further west (Resource Industry Network, 2024). The Peak Downs Highway provides access from Mackay for machinery and equipment, service personnel, fly in/fly out (FIFO) and drive in/drive out (DIDO) mining workers, residents of the mining and agricultural towns and supplies for these communities. Although there are no mines in the Mackay LGA, the economy is dominated by mining and resources. Mackay has become a world-renowned mining equipment technology and services (METS) and engineering innovation centre and provides logistics and service support to the mining industry in the Bowen Basin and elsewhere (Resource Industry Network, 2024). Mining also drives other sectors such as rental, hiring & real estate services, construction, accommodation and food services and tourism. Coal from the Bowen Basin is exported through coal loaders at Hay Point and Dalrymple Bay in the Mackay LGA.

During the 1980s and 1990s, there was a convergence of trends and events that forged and intensified links between the Bowen Basin coal mines and Mackay. Road and rail links provided the physical infrastructure. Coal was transported by rail for export, while the Peak Downs Highway enabled people and goods to travel between the two. Later, the weakening of union power, the downturn in the coal industry caused by the Asian Financial Crisis, the restructuring of the global mining industry, and the mechanisation of the coal mining industry interacted to create an industry in which the use of contractors and the outsourcing of goods and services to and from Mackay had become an integral part of the Bowen Basin coal mining industry (Barry and Waring, 1999; Bowden, 2003; Garnaut, 2002; Waring, 2005; Waring et al., 2000).

Mining is now the largest contributor to economic output in Mackay, generating an estimated annual output of more than AU$7 billion in 2023 (Remplan, 2024), by and large receiving continuous support from the Australian policy landscape (Gruenhagen and Cox, 2025). Mining is also the leading exporter from the region (Remplan, 2024). The resources sector contributed AU$18.4 billion to the Mackay region in 2023, equating to 91 % of gross regional product (Queensland Resources Council, 2023). Mackay also has a strong agriculture industry,

dominated by sugar growing and milling, albeit contributing considerably less to the economy compared with mining (Remplan, 2024; Resource Industry Network, 2024). The workforce in Mackay is dominated by technicians, trade workers, machinery operators and drivers (Australian Bureau of Statistics, 2021).

4.2. Results of thematic analysis

We uncovered 17 first-order themes which we categorised into 5 second-order themes. These second-order themes were then organised into two thematic areas: *Industrial and Regional Structure* and *Firm- and Regional-Level Diversification Dynamics*. After presenting our insights derived from the two thematic areas covering structure and dynamics of a regional innovation system, we elaborate on implications for new path development.

4.2.1. Industrial and regional structure

Second- and first-order themes in this thematic area, including brief descriptions, are summarised in Table 2. These themes give insights into *industry structure*, the *structure of innovation*, and the *support structure* of the case study region. Each of the second-order themes comprises two to three first-order themes.

Our findings suggest that the regional innovation system is characterised by a distinct *industrial specialisation* with firms deeply embedded in the mining sector and its networks, routines, and norms. The focus on and embeddedness in the mining sector is associated with the perception that entering other sectors is challenging since firms lack necessary industry-specific knowledge and networks. Focus and embeddedness in mining are intensified by the *spatial location* of the region; with the Mackay region being distant to other significant industrial clusters, which are located more than 300 km away from Mackay. A structural characteristic of the mining industry is its *boom-and-bust cycles*. Mining boom periods present favourable business conditions for the sector, resulting in the allocation of most resources into the mining sector, while constraining resources for activities outside of mining. On the contrary, episodes of bust cycles constitute a push factor to seek for alternative opportunities outside of the mining sector.

> "We talked about looking at foreign markets with a few people; and the hard part is when you are in a boom situation, you don't have the time to look at investment because […] you are literally so flat-out doing what you are doing right now, that you don't have the time to look at foreign markets or innovation. You are literally trying to get the work through. Then the industry goes to a lull. You have to have the money to then do the investment, to look at the innovation. So it is a real balancing act […] chasing foreign markets, still looking at diversification and having that ticking away; so that if the industry falls again - which it always will; it has over decades - something to back you up, so that you have diversified. Because having your whole market just in coal or just in the Bowen Basin is a huge risk."

Quote from Interview #9 (Regional industry organisation).

The *structure of innovation* in the regional innovation system is reflective of the region's industrial structure. The Mackay region is characterised by an *innovation cluster* that centres on the mining and mining support industry. Over decades, networks and a sense of belonging ("mateship") have evolved, reinforcing the focus on innovation for the mining sector. Faced with technical and operational problems and challenges in the industry, mining suppliers attempt to continually advance products and services to provide improved solutions to their customers in the mining sector.

> "It is a competitive yet companionship that they have in problem-solving. We have got this issue, 'the buckets are too heavy'; the wear and tear on the hydraulics and the booms and the sticks and all that sort of stuff associated with an excavator, it's just too much, 'How can we lessen that?' They might be sitting down at the […] hotel on a Friday night and just talking this over, 'I have come up with this idea', just draw it on the back [of] a coaster […]. And it's that type of innovative thinking and the mateship and the companionship and the compassion, I suppose, to solve that problem; to make something different that gets out into the world market."

Quote from Interview #6 (Firm based in the region).

While firms engage in continuous improvement and incremental innovation, and to some extent conduct research and development activities in-house, often triggered by problems encountered in practice, the *research infrastructure* of the region is limited in their collaborative scope with external research institutes or universities. While firms show interest in collaboration, these often fail to be established due to differing interests and goals of the parties, as well as challenges forming networks with researchers.

The *support structure* in the regional innovation systems aligns with both industry structure and structure of innovation being centred on the mining sector. Industry associations local to the region and relevant national organisations constitute an institutional framework that reinforces embeddedness in and focus on the mining sector. Firms are organised in dense networks facilitated by industry associations that foster and promote opportunities, collaboration and innovation in the

Table 2
Thematic area: Industrial and regional structure.

Second-order theme	First-order theme	Description of theme	Associations with different types of new path development
Industry structure	Industrial specialisation	Firm actors specialised in the mining sector and embedded in its networks perceiving entering other industries as challenging due to unfamiliarity, lack of networks and lack of industry knowledge.	Path extension
	Spatial location	Region and local firms specialised in mining industry, while being located geographically distant to other industry clusters, leaving the region vulnerable to the phase-out of coal mining.	Path extension
	Mining boom-bust cycles	Mining booms disincentivising diversification due to favourable business opportunities as well as resource- and time-constraints, whereby mining downturns pushing firms to diversify to protect them against lost business opportunities.	Path extension; Path branching
Structure of innovation	Innovation cluster	Region a spatial cluster of innovation and technology for the mining sector, characterised by continual improvements, collaborative problem-solving and mateship.	Path extension; Path modernisation
	Research infrastructure	Firms conducting in-house R&D and showing appetite for collaboration with universities and research institutes to boost R&D, knowledge generation, and legitimacy; however, collaboration limited due to misalignments in interests, goals and timeframes, and networking challenges.	Path extension; Path modernisation
Support structure	Industry associations	Regional and national industry associations and initiatives being highly active in the region, supporting innovation, collaboration and commercialisation in the mining industry, while reinforcing dense networks within this sector.	Path extension
	Government support	Broad range of government advice and assistance for international trade and expansion perceived as useful by firms. However, government funding reinforces a narrow focus on the mining sector and lacks support for diversification.	Path extension

mining industry, with a salience that overshadows other industrial sectors. These mechanisms are further aggravated by paradigms and narratives of the region being home to leaders in mining innovation, propagated by industry associations and institutions. Similarly, *government support* activities reinforce the mining focus of the region. Government institutions, programs and support services, while being perceived as useful by firms, are often directed at expanding activities in the mining sector regionally, nationally and globally, while to a lesser extent incorporating advice and support for diversifying markets and industries.

> "There is a lot of emphasis and funding around entrepreneurship, about innovation; a lot in the METS sector at the moment, […] which is great; but if you are asking for people to diversify away from METS to make them more resilient; the money is funding them to focus on the METS sector. […] So I think sometimes our funding streams and our pushes keep people narrow."
>
> Quote from Interview #4 (Regional government).

4.2.2. Firm- and Regional-Level Diversification Dynamics

Second- and first-order themes in this thematic area, including brief descriptions, are summarised in Table 3. While the first thematic area – Industrial and Regional Structure – predominantly encompassed structural aspects and their associated influence on the regional innovation system examined, this thematic area focusses on evidence of diversification dynamics that emerged from the data. Here, we categorised diversification dynamics into two levels: *Firm-level diversification dynamics* and *system-level diversification dynamics*. Each of these 2 second-order themes comprise five first-order themes.

Regarding *firm-level diversification dynamics*, firms in the regional innovation system exert *agency* by proactively engaging or attempting to engage in diversification activities. We found evidence of firms primarily embedded in the mining sector attempting to reduce their reliance on coal by innovating with the goal to expand their business activities beyond the mining industry and the geographic scope of their prior business activities. The mechanisms through which to achieve this involve *entering new industries* and *entering other markets*. The latter approach increases the geographic reach of firms by entering mining regions in other parts of Australia or overseas. In this case, products and services are merely adapted to market-specific conditions, such as meeting regulatory requirements or aligning to different operational routines in other jurisdictions. *Entering new industries*, however, reflects activities of mining suppliers diversifying into other sectors, including mining-related industries, energy, defence and construction. Firms often recognise that they can *utilise transferable skills* to service other sectors, adapt products initially developed for the mining sector to other industries, or utilise their technical skills and capabilities to develop new products and services for other sectors. However, a common challenge is a *lack of resources* which constraints firms to business-as-usual, suffering from a scarcity of time and financial resources to actively engage in activities that could lay the foundation for firm-level diversification.

> "We are looking at industries which are complementary. So identifying that our skills base is our skills base and that's a huge platform in which to grow into other areas. […] We look for new export markets; even new intrastate markets […]. So it's about leveraging existing skills […] because that's got to be your easiest quick win. But it is also with defence. There are so many similarities between what we have to do as METS manufacturing businesses, […] so we pursue those. Obviously, things like BioFutures, AgTech, they have similarities in terms of the componentry, the innovation that is required, just down to basics. You are not having to re-tool the workshop."

Table 3
Thematic area: Firm- and regional-level diversification dynamics.

Second-order theme	First-order theme	Description of theme	Associations with different types of new path development
Firm-level diversification dynamics	Agency of firms	Individual firms being proactive and championing diversification by reducing reliance on the coal mining industry and developing innovative products and services for other sectors.	Path branching
	Entering new industries	Firms recognising or exploiting opportunities to diversify into related sectors, including resources other than coal.	Path branching
	Entering other markets	Firms recognising or exploiting opportunities to diversify by entering other markets, such as by expanding to other coal mining jurisdictions or by exporting.	Path extension
	Utilising transferable capabilities	Skills and capabilities of firms developed in the mining sector seen as transferable to other industries, such as that specified skills, products, services and innovations can be adapted for other industries.	Path branching
	Lacking resources	Resource-constraint firm actors requiring additional resources to innovate and diversify into other sectors.	Path extension
System-level diversification dynamics	Identifying need to diversify	Sentiment that firms and the region need to diversify and develop an exit strategy for coal, requiring a big shift and a mindset change.	–
	Perceiving no need to diversify	Firms and non-firm actors reinforcing that coal mining has a longer-term future, not seeing a need or urgency to diversify.	Path extension
	Discussing potential new sectors	Debates and ideas around potential new industries that could settle in the region, or other industries outside of the region to be serviced by the region.	Path branching; Path importation
	Lacking a shared vision	Lack of shared vision for the future of the region; sentiment that review and mapping of capabilities of the region is required to shape future paths.	Path extension

(*continued on next page*)

Table 3 (*continued*)

Second-order theme	First-order theme	Description of theme	Associations with different types of new path development
	Limited government orchestration	Support and orchestration from institutions and government is lacking to support diversification activities; limited trust in visions and strategies of the government to outline future paths for the region.	Path extension

Quote from Interview #2 (Regional industry association).

System-level diversification dynamics are those that emerged from the data describing dynamics beyond the level of individual firm actors.[2] While individual firms do engage or attempt to engage in diversification activities, the broader system-level perception about the need for firms and the region to diversify is conflicting. While parts of the regional innovation system *identify the need to diversify*, other dynamics *perceive no need to diversify*. The conflicting perspective is primarily rooted in different perceptions of the future of coal mining. While some constituents of the system reinforce the future of coal mining and hence see no grounds for diversification, others perceive the need for a big shift and a mindset change due to an expected decline of coal mining. However, *discussions about potential new sectors* for the region are prevalent, with actors debating ideas about new industries to settle in the region, or to be serviced outside of the region. Data suggests though that the region *lacks a shared vision* for the future, partly associated with *limited government orchestration* to support regional diversification and to formulate visions and strategies for future paths. For example, despite ideas and debates about potential future paths, a broader orchestration from government actors is largely absent. As such, diversification dynamics can primarily be observed on the firm-level, with a lack of system-level coordination.

4.3. Evidence of firm- and system-level agency

Our data suggests evidence of firm-level agency in the Mackay regional innovation system, but, by and large, a lack of system-level agency that goes beyond individual firm actors. Individual firms are agentic by engaging in innovative entrepreneurship – including developing new products and services that target sectors and markets other than mining. For example, individual firms engage in activities and initiatives related to renewable energy, defence, biofutures or agricultural technology. These actions are motivated by founders and managers of small and medium-sized enterprises who discover and exploit opportunities in other areas – often based on skills and capabilities developed in the mining sector and driven by a perceived need to diversify. In this context, individual actors have the agency to change the trajectory within their firm boundaries. At this stage, however, agency is rather isolated and limited to the firm context, constrained by system-level agency being mostly absent. While individual firms are agentic, a critical mass appears to be absent to exert agency on the system level – partly due to conflicting perceptions and visions (for example, related to the future of coal mining). As such, there appears to be a lack of agency to change institutions and structures, with firms and other actors lacking initiatives towards institutional entrepreneurship.

The organisation and orchestration of actors in the Mackay region largely reinforces the mining path. Government, policy and industry associations predominantly focus on mining and strengthening associated structures and institutions, with little evidence of initiatives or place-based leadership that provides system-level agency for a direction of change. Interviewees stated that there is a lack of leadership for new directions. While isolated policy debates and ideas refer to different directions for the region (for example, identifying potential alternative industries that could be a 'good fit' for the region), their coordination or orchestration, so far, has not occurred. Interviewees stated a lack of a clear vision and strategies for the future. Associated with this, our data does not indicate agency on the system level that would gear towards such changes – at least not in a meaningful way, neither through collaborative efforts of multiple actors, nor through government orchestration. In these regards, system-level agency in and for the Mackay region appears to be less oriented towards change, and more towards maintenance. Change agency from within firm boundaries, however, is clearly present. If this agency has the potential to initiate broader regional-level diversification beyond the boundaries of a firm remains unclear.

4.4. Implications for new path development

Insights from our data on structure, dynamics, and firm- and system-level agency have analytical implications for the emergence of new growth paths in the Mackay regional innovation system. Despite the presence of firm-level agency, very limited system-level agency restrains the extent of potential regional change (see Fig. 1, and the last columns of Tables 2 and 3). In our case study region, structure, dynamics and limited change agency appear to predominantly reinforce path extension. Industrial specialisation and spatial location form a structural building block that reinforces a coal and mining focus. This is accompanied by industry associations and government support tailored towards mining. Likewise, a lack of a shared vision, no perceived need to alter the path, and limited government orchestration for diversification affirm the current path and impede alternative trajectories.

However, there are indications for other growth paths emerging, largely due to firm-level agency. The region is a cluster of innovation with firms proactively innovating, sometimes in collaboration with research institutes, and thereby improving products, services, and processes, or developing entirely new products for the sector. These dynamics are reflective of enabling path modernisation, however, also fostering the extension of the current path by reinforcing the mining focus. The agency of individual firms that build upon transferable skills to innovate and adapt products and services to enter new sectors enables path branching. Thereby, firms seek new growth paths by branching into related sectors and industries which may have implications for the system as a whole. Mining boom-bust cycles are an interesting region- and industry-specific phenomenon, both facilitating path extension and stimulating path branching. During mining boom times, firms and the region are incentivised to continue the current path, limiting change agency, while the expectation of mining downturns pressures firms to explore alternatives and branch into other industries. While the data suggests that there are pockets of discussion about potential new sectors for the region, it primarily is geared towards path branching, whereby the importation of a new path remains largely visionary.

5. Discussion and conclusions

The analysis of our case study data draws a rich picture of a regional innovation system structurally anchored in traditional industries in the resources sector, yet demonstrating evidence of innovation that goes beyond mere incremental improvements. Following the classification of

[2] It should be noted that we view firms as being an integral part of the system. The empirical categorisation into firm and system level reflects diversification dynamics originating from within firms as opposed to diversification dynamics outside of organisational boundaries, spanning multiple levels and organisations.

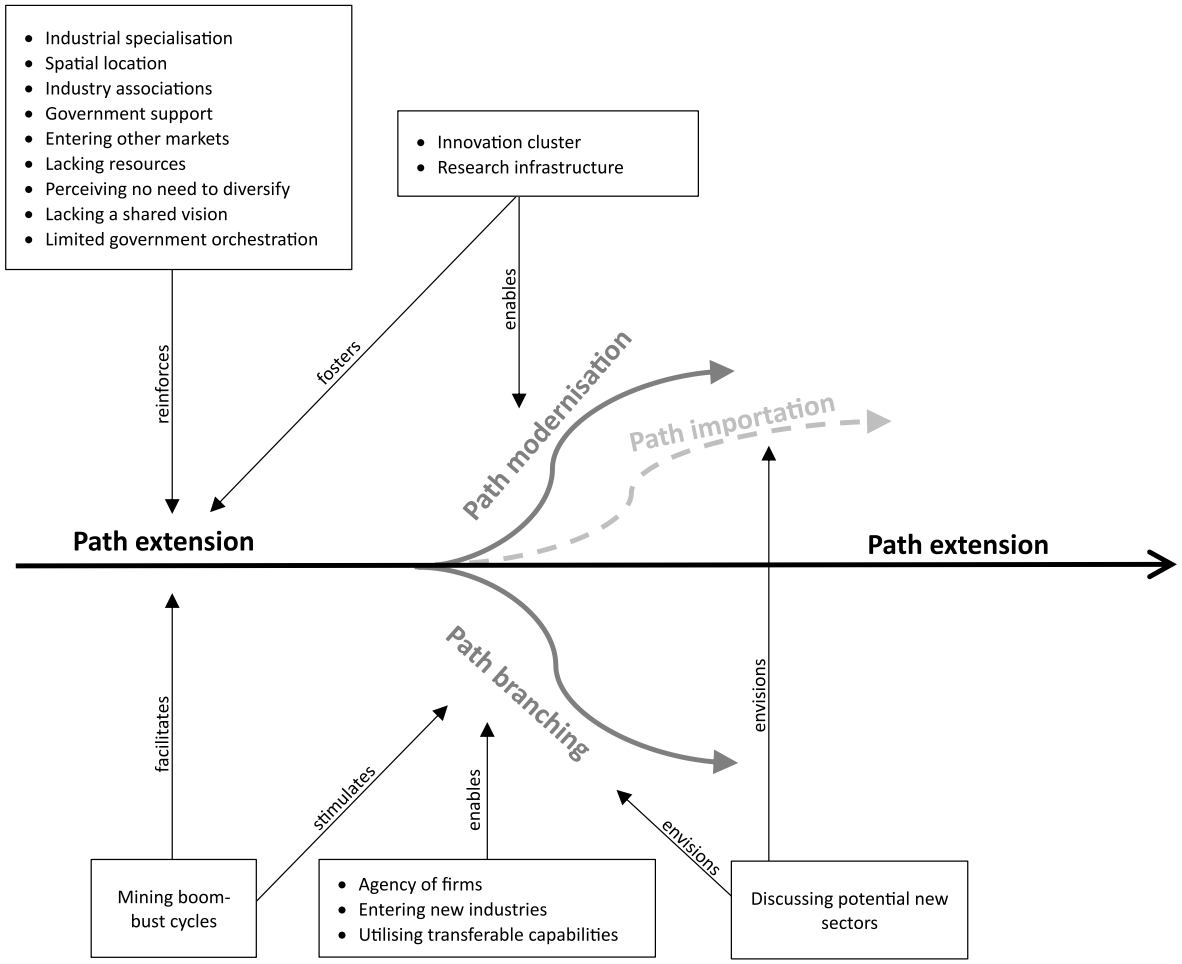

Fig. 1. Themes and associations with different types of new path development.

Isaksen et al. (2018), our findings suggest that the Mackay region can be described as an organisationally thick and specialised regional innovation system. The region and its firms specialise in the mining and related sectors, institutions and organisations reinforce this specialisation, and firm and institutional actors are embedded in networks based on the industrial setup (cf. Isaksen et al., 2018). In line with conceptualisations by Isaksen et al. (2018), we found that structure and dynamics of the region, and associated firm- and system-level agency, suggest that growth paths predominantly emerge around path extension and path modernisation. As such, the Mackay region is at risk of becoming path-dependent, with institutions, infrastructure, local assets and industrial specialisation being geared toward the mining sector (Martin and Sunley, 2006; Sun et al., 2024), lacking system-level agency to change the current path. The dominance of industry regime and structure, including knowledge, networks, and soft institutions, imply that changes are difficult to implement (Boschma et al., 2017), whereby the region may be prone to a lock-in (Isaksen et al., 2018).

However, conceiving the concept of lock-ins as multi-dimensional involving functional, cognitive and political dimensions (Grabher, 1993), the trajectory is less explicit. Functionally, the region is characterised by structures and networks of firms and institutions stabilising an industrial regime that is centred on the mining industry. The embeddedness in a spatial location, sector-specific networks and supplier relationships reinforce the specialisation on mining, and particularly coal mining, while impeding boundary-spanning activities (Grabher, 1993). Firms face difficulties and resource constraints to escape functional lock-ins and enter sectors beyond mining. However, individual firm champions, partially driven by the cyclic nature of mining boom and bust periods, demonstrate agency through innovative activities that tap into other industries and sectors. These are facilitated by an entrepreneurial mindset and perceiving opportunities for adapting skills and capabilities originally developed in the mining sector to other use cases. We did not see a clear cognitive lock-in in the region. While parts of the innovation system exhibit a mutual orientation, social processes and a worldview that reinforce a focus on mining (Grabher, 1993), this focus remains contested among firm and institutional actors. The mere presence of visions and pockets of concrete actions suggest dynamics are present that ultimately are aimed towards breaking through path dependence – these dynamics, however, appear to be in their infancy. Institutional and government actions imply a partial political lock-in (Grabher, 1993) – at least concerning the specific regional innovation system. This is in part due to limited government orchestration that could lay the groundwork for alternative paths.

Theoretically, external factors or exogenous shocks have the potential to change the path of a region and its innovation system (Martin and Sunley, 2006). In our case, the phase-out of coal could constitute an exogenous shock which may either lead to a path dependence turning into a negative lock-in, or push the region to renew its industrial setup (Martin and Simmie, 2008; Martin and Sunley, 2006). For our case study region, either trajectory appears to be possible. While the structure of the regional innovation system with its setup of firms and institutions reinforces path extension, and partly path modernisation, risking a lock-in (Isaksen et al., 2018), it is the agency of individual firm actors as part of the system that shows the potential to create new growth path. On the firm level, innovation activities and branching into other industries exhibit pockets of the establishment of new growth paths, in

line with evolutionary economic geography conceptualising firms as important agents to drive change (Binz et al., 2016; Hassink et al., 2019; Tödtling and Trippl, 2013). For example, firms engaged in innovation activities based on their expertise in mining that resulted in the development of new products unrelated to the mining sector, such as in the renewable energy space. Furthermore, firms built upon their experience from the mining sector to develop service solutions applicable to other sectors. Both of these examples of firm-level agency – that is, exerting influence within the organisational boundaries to innovate and diversify – may have the potential to lay the groundwork for change; dynamics similar to those found in other mining regions such as in China and Sweden (Hu and Yang, 2019; Stihl, 2022). Historically, the nature of mining boom-bust cycles has – to some extent – raised awareness among firm actors that diversification is required to absorb shocks of a downturn (Parker and Cox, 2018). However, while we could to some extent observe firm-level agency, system-level agency, while not fully absent, appears to be very limited – as such, there is a lack of system building dynamics and legitimisation of alternative growth paths (Hassink et al., 2019). This is unlike in other mining or former mining regions, where government orchestration played an important role for shaping new growth paths (Hu, 2017; Oei et al., 2020a).

We argue that we can witness sparks of a transformation of a regional innovation system in the Mackay region – albeit in its very infancy. System-level agency and institutional level dynamics, including government orchestration, are only marginally pronounced. However, some extent of system-level agency is present in the form of collaborations within the cluster and among its firms and research institutes to initiate change (Hassink et al., 2019). In particular firms, as the drivers of change from an evolutionary economic geography perspective, exhibit dynamics that have the potential to create pathways for a transformation. Knowledge networks and routines appear to be largely path-dependent (Boschma and Frenken, 2011; Martin and Simmie, 2008; Martin and Sunley, 2006); however, we observed evidence of entrepreneurial firms engaging in innovative and technologically advanced activities advancing the sector (Gruenhagen and Parker, 2020), as well as promoting and actioning diversification through an increasing diversity and variety of knowledge development. Similar dynamics were observed in other mining regions, such as in the case of a mining town in Sweden, where a local mining culture and incumbents discouraged entrepreneurship and change (Stihl, 2022). In this and in our case, it was primarily agency in the form of innovative entrepreneurship that enabled first steps towards new growth paths. In the Swedish case, however, this was accompanied by a larger extent of institutional entrepreneurship and place-based leadership compared to our case. Local capabilities and groundwork dynamics among firms may drive change in the longer term, particularly opening up opportunities for path branching (Chen et al., 2024; Neffke et al., 2018). While the entrepreneurial activities of firms that function as agents of new path development show a potential for new growth paths, they are subject to interactions with system-level actors (Binz et al., 2016; Gruenhagen et al., 2022; Isaksen et al., 2018). As such, pockets of diversification are fragile – with an instability of an agreed-upon vision and strategy, including conflicting views, that could otherwise pave the way for a regional transformation. However, a transformative vision, incorporating local voices and diverse perspectives into government policies and initiatives, is important for systemic changes (Weldegiorgis, 2025), but largely absent in the Mackay region.

Our study implicates avenues for future research. To establish associations between firm-level diversification activities and aggregate-level outcomes for a regional innovation system once industrial decline occurs, a longitudinal study could track structure and dynamics of a regional innovation system over an extensive timeframe. Considering global transitions to a low-emissions future, and declining ore grades, regions relying on the coal industry would form a meaningful context. This endeavour, however, would require substantial resources to realise such an ambitious research project. Future research may also investigate to what extent there are variances among firms as agents of change in different types of regional innovation systems – such as whether there are differences between organisationally thick and organisationally thin regional innovation systems. Another promising opportunity for future studies comprises the use of simulation methods such as agent-based modelling (ABM) to establish linkages between micro-level activities and their impact on system-level dynamics.

In conclusion, our study makes several contributions. By analysing a regional innovation system heavily dependent on the mining industry in the context of global transitions to a low-emissions future, we integrate regional innovation systems, evolutionary economic geography and agency perspectives to uncover structure and dynamics that allow drawing implications for the transformation of a region. We therefore substantiate the empirical applicability of an integrated framework to derive insights into firm- and system-level agency in the context of a regional innovation system (cf. Tödtling and Trippl, 2013). By extracting firm- and system-level agency, whereby we view firms as an integral part of the system, we highlight the cross-level nature of regional diversification and transition. We also establish the relevance of the interplay between structure of and dynamics in a region, intersecting regional innovation systems and evolutionary economic geography perspectives (Hassink et al., 2019; Tödtling and Trippl, 2013). By presenting a fine-grained analysis of the multi-dimensionality of lock-ins, we demonstrate that functional, political and cognitive lock-ins occur not only on a regional level but also on a firm level, reinforcing the need for a differentiated analysis on multiple levels to capture endogenous change (Hassink, 2010b; Martin, 2010).

Empirically, we analyse a region not in retrospect after an exogenous shock has occurred, such as the decline of an industry, but during a period of relative stability – albeit with expectations of a phase-out of coal in the longer term. This allowed us to illustrate dynamics across the firm and system level that reinforce or challenge the path dependence of a region *before* a potential period of industrial and regional decline. Thereby, we were able to highlight the agency of firm actors for laying the groundwork for diversification and driving change at a point in time before economic conditions are unambiguously pressing for change. This emphasises the importance of the role of visions, expectations and entrepreneurial orientation among firms to ignite diversification activities and change – and shows variances that were observed among innovation system actors in their judgement of potential external shocks that may affect them in the future. By disentangling firm- and system-level agency, we were able to highlight that in this specific case firm-level agency prevails over system-level agency. The illustrated lack of pronounced system-level agency suggests the prevalence of obstacles for a regional transition.

CRediT authorship contribution statement

Jan Henrik Gruenhagen: Writing – original draft, Visualization, Validation, Methodology, Investigation, Formal analysis, Conceptualization. **Janice Terrill:** Writing – review & editing, Validation, Investigation, Formal analysis, Data curation. **Stephen Cox:** Writing – review & editing, Validation, Project administration, Funding acquisition, Data curation, Conceptualization.

Funding

This research was undertaken with the support of the Queensland Government Department of State Development, Manufacturing, Infrastructure and Planning.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Stephen Cox reports financial support was provided by Queensland

Government Department of State Development, Manufacturing, Infrastructure and Planning. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The authors do not have permission to share data.

References

Alexandra, J., 2017. Water and coal – transforming and redefining 'natural' resources in Australia's latrobe region. Australas. J. Reg. Stud. 23 (3), 358–381.

Asheim, B.T., Gertler, M.S., 2006. The geography of innovation: regional innovation systems. In: Fagerberg, J., Mowery, D.C. (Eds.), The Oxford Handbook of Innovation. Oxford University Press. https://doi.org/10.1093/oxfordhb/9780199286805.003.0011.

Asheim, B.T., Grillitsch, M., Trippl, M., 2016. Regional innovation systems: past–present–future. Handbook on the Geographies of Innovation 45–62.

Auerbach, C., Silverstein, L.B., 2003. Qualitative Data: an Introduction to Coding and Analysis, 21. NYU Press. https://doi.org/10.18574/nyu/9780814707807.

Australian Bureau of Statistics, 2021. Mackay 2021 census. Retrieved 30 September 2024 from. https://abs.gov.au/census/find-census-data/quickstats/2021/LGA34770.

Barry, M., Waring, P., 1999. Shafted': Labour Productivity and Australian Coal Miners *Journal of Australian Political Economy*, pp. 89–112, 44.

Baumgartinger-Seiringer, S., 2022. The role of powerful incumbent firms: shaping regional industrial path development through change and maintenance agency. Regional Studies, Regional Science 9 (1), 390–408.

Benner, M., 2024. System-level agency and its many shades: path development in a multidimensional innovation system. Reg. Stud. 58 (1), 238–251.

Bergek, A., Jacobsson, S., Carlsson, B., Lindmark, S., Rickne, A., 2008. Analyzing the functional dynamics of technological innovation systems: a scheme of analysis. Res. Pol. 37 (3), 407–429. https://doi.org/10.1016/j.respol.2007.12.003.

Binz, C., Truffer, B., Coenen, L., 2016. Path creation as a process of resource alignment and anchoring: industry formation for on-site water recycling in beijing. Econ. Geogr. 92 (2), 172–200.

Boschma, R., Coenen, L., Frenken, K., Truffer, B., 2017. Towards a theory of regional diversification: combining insights from evolutionary economic geography and transition studies. Reg. Stud. 51 (1), 31–45.

Boschma, R., Frenken, K., 2011. The emerging empirics of evolutionary economic geography. J. Econ. Geogr. 11 (2), 295–307.

Boschma, R.A., Frenken, K., 2006. Why is economic geography not an evolutionary science? Towards an evolutionary economic geography. J. Econ. Geogr. 6 (3), 273–302. https://doi.org/10.1093/jeg/lbi022.

Bowden, B., 2003. Regulating outsourcing: the use of contractors on the central Queensland coalfields, 1974–2003. Lab. Ind.: a journal of the social and economic relations of work 14 (1), 41–57.

Brauers, H., Oei, P.-Y., Walk, P., 2020. Comparing coal phase-out pathways: the United Kingdom's and Germany's diverging transitions. Environ. Innov. Soc. Transit. 37, 238–253. https://doi.org/10.1016/j.eist.2020.09.001.

Burke, P.J., Best, R., Jotzo, F., 2019. Closures of coal-fired power stations in Australia: local unemployment effects. Aust. J. Agric. Resour. Econ. 63 (1), 142–165.

Cała, M., Szewczyk-Świątek, A., Ostręga, A., 2021. Challenges of coal mining regions and municipalities in the face of energy transition. Energies 14 (20), 6674.

Cantwell, J., Fai, F., 1999. Firms as the source of innovation and growth: the evolution of technological competence. J. Evol. Econ. 9 (3), 331–366. https://doi.org/10.1007/s001910050086.

Chen, Y., Wang, Y., Zhao, C., 2024. From riches to digitalization: the role of AMC in overcoming challenges of digital transformation in resource-rich regions. Technol. Forecast. Soc. Change 200. https://doi.org/10.1016/j.techfore.2023.123153. Article 123153.

Chlebna, C., Martin, H., Mattes, J., 2023. Grasping transformative regional development–exploring intersections between industrial paths and sustainability transitions. Environ. Plan. A Econ. Space 55 (1), 222–234.

Coenen, L., Campbell, S., Wiseman, J., 2018. Regional innovation systems and transformative dynamics: transitions in coal regions in Australia and Germany. In: Isaksen, A., Martin, R., Trippl, M. (Eds.), New Avenues for Regional Innovation Systems - Theoretical Advances, Empirical Cases and Policy Lessons. Springer, pp. 199–217.

Cooke, P., Uranga, M.G., Etxebarria, G., 1997. Regional innovation systems: institutional and organisational dimensions. Res. Pol. 26 (4–5), 475–491.

de Villiers Scheepers, M.J., de Klerk, S., Renando, C., Verreynne, M.-L., 2021. Greater Whitsunday Region: Regional Innovation Benchmark Research Report: 2020-2021. U. o. t. S. Coast.

Diluiso, F., Walk, P., Manych, N., Cerutti, N., Chipiga, V., Workman, A., Ayas, C., Cui, R. Y., Cui, D., Song, K., 2021. Coal transitions—part 1: a systematic map and review of case study learnings from regional, national, and local coal phase-out experiences. Environ. Res. Lett. 16 (11), 113003.

Feng, K., Song, K., Viteri, A., Liu, Y., Vogt-Schilb, A., 2023. National and local labor impacts of coal phase-out scenarios in Chile. J. Clean. Prod. 414, 137399. https://doi.org/10.1016/j.jclepro.2023.137399.

Fleming-Muñoz, D.A., Poruschi, L., Measham, T., Meyers, J., Moglia, M., 2020. Economic vulnerability and regional implications of a low carbon emissions future. Aust. J. Agric. Resour. Econ. 64 (3), 575–604.

Garnaut, R., 2002. Australia as a branch office economy. Aust. J. Agric. Resour. Econ. 46 (3), 447–461.

Garud, R., Karnoe, P., 2013. Path Dependence and Creation. Lawrence Erlbaum Associates.

Geels, F.W., 2011. The multi-level perspective on sustainability transitions: responses to seven criticisms. Environ. Innov. Soc. Transit. 1 (1), 24–40. https://doi.org/10.1016/j.eist.2011.02.002.

Gertler, M.S., 2010. Rules of the game: the place of institutions in regional economic change. Reg. Stud. 44 (1), 1–15.

Gong, H., Binz, C., Hassink, R., Trippl, M., 2022. In: Emerging Industries: Institutions, Legitimacy and system-level Agency, vol. 56. Taylor & Francis, pp. 523–535.

Grabher, G., 1993. The weakness of strong ties: the lock-in of regional development in Ruhr area. In: Grabher, G. (Ed.), The Embedded Firm: on the Socioeconomics of Industrial Networks. Routledge, pp. 255–277.

Grillitsch, M., Sotarauta, M., 2020. Trinity of change agency, regional development paths and opportunity spaces. Prog. Hum. Geogr. 44 (4), 704–723.

Gruenhagen, J.H., Cox, S., 2025. How do politics, news media and the public frame the discourse on coal mining? Implications for the legitimacy, (de)stabilisation and transition of an industry regime. Technol. Forecast. Soc. Change 218, 124217. https://doi.org/10.1016/j.techfore.2025.124217.

Gruenhagen, J.H., Cox, S., Parker, R., 2022. An actor-oriented perspective on innovation systems: functional analysis of drivers and barriers to innovation and technology adoption in the mining sector. Technol. Soc. 68, 101920.

Gruenhagen, J.H., Parker, R., 2020. Factors driving or impeding the diffusion and adoption of innovation in mining: a systematic review of the literature. Resour. Policy 65, 101540. https://doi.org/10.1016/j.resourpol.2019.101540.

Guion, L.A., 2002. Triangulation: establishing the validity of qualitative studies. Environ. Data Inf. Serv. 2002 (6).

Hassink, R., 2007. The strength of weak lock-ins: the renewal of the westmünsterland textile industry. Environ. Plan. A Econ. Space 39 (5), 1147–1165.

Hassink, R., 2010a. Locked in decline? On the role of regional lock-ins in old industrial areas. In: Boschma, R., Martin, R. (Eds.), The Handbook of Evolutionary Economic Geography. Edward Elgar Publishing.

Hassink, R., 2010b. Regional resilience: a promising concept to explain differences in regional economic adaptability? Camb. J. Reg. Econ. Soc. 3 (1), 45–58.

Hassink, R., Isaksen, A., Trippl, M., 2019. Towards a comprehensive understanding of new regional industrial path development. Reg. Stud. 53 (11), 11636–11645.

Hu, X., 2017. From coal mining to coal chemicals? Unpacking new path creation in an old industrial region of transitional China. Growth Change 48 (2), 233–245. https://doi.org/10.1111/grow.12190.

Hu, X., Yang, C., 2019. Institutional change and divergent economic resilience: path development of two resource-depleted cities in China. Urban Stud. 56 (16), 3466–3485. https://doi.org/10.1177/0042098018817223.

Isaksen, A., 2001. Building regional innovation systems: is endogenous industrial development possible in the global economy? Can. J. Reg. Sci. 24 (1), 101–120.

Isaksen, A., Stig-Erik, J., Rune, N., Normann, R., 2019. Regional industrial restructuring resulting from individual and system agency. Innovat. Eur. J. Soc. Sci. Res. 32 (1), 48–65. https://doi.org/10.1080/13511610.2018.1496322.

Isaksen, A., Tödtling, F., Trippl, M., 2018. Innovation policies for regional structural change: combining actor-based and system-based strategies. In: Isaksen, A., Martin, R., Trippl, M. (Eds.), New Avenues for Regional Innovation Systems - Theoretical Advances, Empirical Cases and Policy Lessons. Springer.

Isaksen, A., Trippl, M., 2016. Path development in different regional innovation systems: a conceptual analysis. In: Parrilli, M.D., Fitjar, R.D., Rodriguez-Pose, A. (Eds.), Innovation Drivers and Regional Innovation Strategies. Routledge, pp. 66–84.

Ivanova, G., 2014. The mining industry in Queensland, Australia: some regional development issues. Resour. Policy 39, 101–114.

Jolly, S., Grillitsch, M., Hansen, T., 2020. Agency and actors in regional industrial path development. A framework and longitudinal analysis. Geoforum 111, 176–188. https://doi.org/10.1016/j.geoforum.2020.02.013.

Mackay Regional Council, 2023. Annual report 2022-2023. https://www.mackay.qld.gov.au/_data/assets/pdf_file/0009/347571/Annual_Report_22-23_FINAL_WEB.pdf.

MacKinnon, D., Dawley, S., Pike, A., Cumbers, A., 2019. Rethinking path creation: a geographical political economy approach. Econ. Geogr. 95 (2), 113–135.

Martin, H., Martin, R., Zukauskaite, E., 2019. The multiple roles of demand in new regional industrial path development: a conceptual analysis. Environ. Plan. A Econ. Space 51 (8), 1741–1757.

Martin, R., 2010. Roepke lecture in economic geography—rethinking regional path dependence: beyond lock-in to evolution. Econ. Geogr. 86 (1), 1–27.

Martin, R., 2013. Path dependence and the spatial economy: a key concept in retrospect and prospect. Handbook of regional science 609–629.

Martin, R., Simmie, J., 2008. Path dependence and local innovation systems in city-regions. Innovat. Manag. Pol. Pract. 10 (2–3), 183–196.

Martin, R., Sunley, P., 2006. Path dependence and regional economic evolution. J. Econ. Geogr. 6 (4), 395–437.

Matern, A., Špaček, M., Theuner, J., Knippschild, R., Janáček, J., 2023. Strategies for energy transition and regional development in European post-coal mining regions: Ústí region, Czechia, and Lusatia, Germany. Territory, Politics, Governance 1–22. https://doi.org/10.1080/21622671.2023.2231972.

Neffke, F., Hartog, M., Boschma, R., Henning, M., 2018. Agents of structural change: the role of firms and entrepreneurs in regional diversification. Econ. Geogr. 94 (1), 23–48.

Oei, P.-Y., Brauers, H., Herpich, P., 2020a. Lessons from Germany's hard coal mining phase-out: policies and transition from 1950 to 2018. Clim. Policy 20 (8), 963–979.
Oei, P.-Y., Hermann, H., Herpich, P., Holtemöller, O., Lünenbürger, B., Schult, C., 2020b. Coal phase-out in Germany – implications and policies for affected regions. Energy 196, 117004. https://doi.org/10.1016/j.energy.2020.117004.
Parker, R., Cox, S., 2018. How the globalisation and financialisation of mining majors affects linkage development with local engineering and technology suppliers in the Queensland resources industry. Resour. Policy 58, 125–130. https://doi.org/10.1016/j.resourpol.2018.04.002.
Parrilli, M.D., Fitjar, R.D., Rodríguez-Pose, A., 2016. Innovation Drivers and Regional Innovation Strategies. Routledge.
Patton, M.Q., 2022. Qualitative Research & Evaluation Methods, third ed. Sage Publications.
Queensland Resources Council, 2023. Mackay a 'resources workhorse' for Qld. https://www.qrc.org.au/mackay-a-resources-workhorse-for-qld/#:~:text.
Remplan, 2024. Mackay economy, jobs and business insights. https://app.remplan.com.au/mackay/economy/industries/output?state=QG0WsX!J6KZCJmq8fKbJZnHWeeG1SZiASor7t7DqDES2BOBAIpS5RiaS2UAAVZTbQn.
Resource Industry Network, 2024. Best in METS. Retrieved 30 September 2024 from. https://www.resourceindustrynetwork.org.au/About/Best-in-METS.
Saldaña, J., 2021. The Coding Manual for Qualitative Researchers, fourth ed. SAGE Publications.
Saunders, M.N., Lewis, P.E.T., Thornhill, A., 2009. Research Methods for Business Students, fifth ed. Pearson Education.
Sotarauta, M., Grillitsch, M., 2023. Studying human agency in regional development. Reg. Stud. 57 (8), 1409–1414. https://doi.org/10.1080/00343404.2023.2217224.
Srivastava, P., Hopwood, N., 2009. A practical iterative framework for qualitative data analysis. Int. J. Qual. Methods 8 (1), 76–84. https://doi.org/10.1177/160940690900800107.
Stihl, L., 2022. Challenging the set mining path: agency and diversification in the case of Kiruna. Extr. Ind. Soc. 11, 101064. https://doi.org/10.1016/j.exis.2022.101064.
Sun, H., Ma, L., Jin, F., Huang, Y., 2024. Path dependence or path creation of mature resource-based cities: a new firm entry perspective. J. Geogr. Sci. 34 (3), 499–526.
Thomson, O., 2023. Mackay crowned Queensland's top resources pillar. Australian Mining. https://www.australianmining.com.au/mackay-crowned-queenslands-top-resources-pillar/.
Tödtling, F., Trippl, M., 2005. One size fits all?: towards a differentiated regional innovation policy approach. Res. Pol. 34 (8), 1203–1219.
Tödtling, F., Trippl, M., 2013. Transformation of regional innovation systems: from old legacies to new development paths. In: Cooke, P. (Ed.), Re-framing Regional Development. Routledge, pp. 297–317.
Tol, R.S., 2018. The economic impacts of climate change. Rev. Environ. Econ. Pol. 12 (1).
Valle de Souza, S., Dollery, B., Blackwell, B., 2018. An empirical analysis of mining costs and mining royalties in Queensland local government. Energy Econ. 74, 656–662. https://doi.org/10.1016/j.eneco.2018.07.016.
Waring, P., 2005. Some employment relations consequences of the merger and acquisition movement in the Australian black coal mining industry 1997-2003. Aust. Bull Lab. 31 (1), 72–88.
Waring, P., Macdonald, D., Burgess, J., 2000. Globalization and confrontation: the transformation of the Australian coal industry. Asia Pac. Bus. Rev. 7 (1), 21–45.
Weldegiorgis, F.S., 2025. Australian coal mining and economic diversification in the energy transition context. Resour. Policy 100, 105429. https://doi.org/10.1016/j.resourpol.2024.105429.
Yin, R.K., 2009. Case Study Research: Design and Methods, vol. 5. Sage.
Zhou, J., Zhang, Z., Xu, X., Chang, D., 2022. Does the transformation of resource-dependent cities promote the realization of the carbon-peaking goal? An analysis based on typical resource-dependent city clusters in China. J. Clean. Prod. 365, 132731. https://doi.org/10.1016/j.jclepro.2022.132731.