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

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A B S T R A C T

The use of coal for energy generation is a major contributor to greenhouse gas emissions, adversely affecting the climate and attempts to achieve net zero. Yet coal mining is also an important pillar of national economies such as Australia, provoking a contested discourse about the legitimacy of coal mining. We conceptualise the framing of coal mining as reflecting legitimacy pressures through discourse and agenda setting in the economic and socio-political environment that may lead to changes in industry regimes. We thereby examine how coal mining is framed within different arenas of discourse, and how this framing has changed over time. Specifically, we apply natural language processing and topic modelling to analyse and compare a large amount of text data capturing parliamentary documents and debates, news media reports and debates in the broader public over a period of more than 30 years. Our findings reveal that the discourse on coal mining among policymakers is dominated by economic framing, as opposed to a strong socio-political framing in the broader public. This suggests a mismatch between how coal mining is viewed by policymakers focussing on economic benefits versus parts of the broader public raising concerns over environmental and climate issues. Framing of the discourse in news media is more balanced. Our analysis demonstrates that the framing of coal mining has remained remarkably consistent, overall suggesting continuous legitimacy and a relatively stable industry regime.

1. Introduction

To limit the effects of climate change and achieve net zero, global emissions from the burning of fossil fuels must rapidly decrease (IEA, 2021). Energy is estimated to contribute more than three quarters of greenhouse gas emissions globally, with coal dominating emissions from fuel combustion (IEA, 2021). There is thus a need to reduce the use of fossil fuels, including coal. Australia is one of the major global producers and exporters of coal (Gibbons, 2023a, 2023b). The production and export of fossil fuels are important contributors to Australia's economic performance, with the overall mining sector contributing to more than 13 % of GDP and more than two-thirds of total merchandise exports (Thurtell, 2023). Diminution of production and exports would thus have significant implications for the economic performance of Australia.

Policy support for the fossil fuel industry in Australia has remained strong (Parker and Cox, 2020), even as the effects of climate change have become more widely accepted. In part, this ongoing support is enabled by global institutional rules for counting greenhouse gas emissions at the country level. A commonly used territorial-based framework attributes emissions to the country where they were released, not where they were extracted. This approach to carbon accounting operates as a demand side policy framework, without considering supply side mechanisms (Lazarus and van Asselt, 2018). Consequently, Australia is able to take a position that the mining and export of fossil fuels is consistent with global approaches to managing climate change as it is the responsibility of importers to reduce their demand by switching to alternative energy sources.

Domestically, climate policy in Australia has been heavily contested. There have been two major policy attempts at the national level to address climate change: The Carbon Pollution Reduction Scheme (CPRS) Bill in 2009, and the Clean Energy Act 2011 (Christoff and Eckersley, 2021). The CPRS was not passed, and the Clean Energy Act repealed in 2014 (Christoff and Eckersley, 2021). As such, these policies had little or no effect on fossil fuel industries. Nonetheless, there have been

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significant public debates about climate change and coal mining. These debates became most pronounced in 2016 when the Adani coal mine was seeking development approval. The large coal mining project in Queensland became a focal point for community resistance to coal mining, driven by climate change concerns and alleged failures of the government to take climate action (Hine et al., 2022). This one project became totemic as a site for pro- and anti-coal mining debates (Jolley and Rickards, 2020).

The imperatives of climate change, with the contested nature of coal mining within Australia as economically important but with growing public concern suggests support for coal mining, historically strong, might be under threat. One way that support for industries, or its decline, is evidenced is in the way an industry is framed within various discourses, including debates undertaken by policymakers, by news coverage, and by debates in the broader public. Despite the significance of coal mining to the Australian economy, and recent movements in other countries to exit coal mining to reduce emissions, there is a surprising lack of research investigating the development and salience of debates on coal mining in Australia in various arenas of discourse to obtain implications for the support or decline of the industry. Previous research in the context of Australia has narrowly focused on individual mining projects – such as the Adani coal mine in the state of Queensland (Stutzer et al., 2021). Related research in other countries has investigated arenas of discourse separately, such as relying on media (Dehler-Holland et al., 2021) or parliamentary debates (Müller- Hansen et al., 2021), respectively, not comparing and contrasting the debate across different arenas of discourse. Theoretically, however, legitimacy pressures that may lead to changes and industrial decline are rooted in discursive debates among various publics – including politics, media and the broader population – ultimately influencing public support and political action (Geels, 2010). Previous research, while empirically interesting, was often not founded in and guided by a theoretical framework. Responding to this gap, the purpose of this paper is to examine how coal mining is framed within and across multiple arenas of discourse in Australia, how this framing has changed over time, and what implications can be drawn for the support or decline of the industry regime. We aim to answer three research questions:

RQ1. How is coal mining framed within discourse by policymakers, news media, and social media?

RQ2. To what extent has the framing of coal mining changed over time?

RQ3. To what extent is the framing of coal mining different between these three arenas of discourse?

To answer our research questions, we collected a large amount of data to uncover the discourse on coal mining in Australia in (1) parliamentary debates and documents, (2) news articles, and (3) in the broader public. We base our analysis on 23,658 unique documents covering a timeframe of more than 30 years. Due to the large amount of data, we apply natural language processing (NLP) and topic modelling techniques to analyse our data. Based on our analysis and by integrating our theoretical framework, we draw implications for the support or decline of coal mining and contextualise the insights considering prior research.

Our study makes several contributions. Theoretically, we demonstrate the utility of integrating different frameworks to conceptualise the framing of coal mining in multiple arenas of discourse as a reflection of agenda setting and legitimacy pressures in the environment. Empirically, we uncover development and salience of the framing of coal mining in an economy heavily reliant on the coal industry by comparing and contrasting multiple arenas of discourse concurrently, thereby providing a holistic rather than an isolated investigation. Methodologically, we illustrate the applicability of machine learning techniques in social sciences research to utilise large amounts of qualitative data that would otherwise remain untapped.

The paper proceeds as follows. First, we review relevant literature and introduce our theoretical framing of the study. Second, we introduce natural language processing (NLP) and topic modelling as tools to assist with the analysis of large quantities of text. Third, the results of our analysis are presented. Finally, we discuss our findings in light of our theoretical framing and prior research.

2. Literature review

In this section, we review the relevant literature to establish the theoretical and empirical foundation of our study. Theoretically, we present changes in the framing of coal mining as an issue of industry transitions and regime destabilisation, induced by legitimacy pressures emerging in the economic and socio-political environment (Section 2.1). We then build upon agenda-setting theory to illustrate how legitimacy pressures in the economic and socio-political environment are materialised through discourse in multiple arenas (Section 2.2). We complement our literature review with a review of prior empirical research into the framing and decline of coal industries. We specifically focus on studies that examined how the topics that frame discussions of coal have changed over time and the implications of these changes for regime destabilisation (Section 2.3).

2.1. Industry transitions and regime destabilisation

A reduction in coal mining necessitates industrial decline. Theory and evidence suggest industry decline does not occur only due to economic factors, such as that an industry is no longer viable due to more cost-effective alternatives (Geels and Gregory, 2023). While firms operate within industry regimes that shape behavioural and strategic patterns, the Triple Embeddedness Framework (TEF) (Geels, 2014) states that firms and industries are also exposed to broader economic and socio-political environments. These environments exert pressures on industry regimes and individual firms (Geels and Gregory, 2023). The consideration of external environments and their categorisation into economic and socio-political pillars makes the Triple Embeddedness Framework highly applicable for investigating social, political and economic pressures in the context of energy transitions (Canal Vieira et al., 2022). Previous literature has demonstrated the usefulness of the framework for analysing transitions of energy sectors, including the phase-out of coal (e.g., Brauers and Oei, 2020; Brauers et al., 2020; Kungl and Geels, 2018; Mühlemeier, 2019; Turnheim and Geels, 2012). The framework is also well-integrated with the notion that changes and pressures in the environment build up over longer timeframes, often involving phases that reflect pressures and reactions from different environments (Penna and Geels, 2012). Accordingly, pressures materialise through issues being raised in the civil society, then spilling over to the broader public, leading to political debates, which may result in new regulations, and finally in changed market and economic conditions (Penna and Geels, 2012). As such, the Triple Embeddedness Framework presents a suitable and fitting approach to analyse stabilising and destabilising factors in the socio-political and economic environments in the context of coal mining.

According to the framework, industries maintain support and are conferred legitimacy from both economic and socio-political environments which co-evolve with industry regimes (Geels, 2014). Regimes are supported by the economic environment to the degree to which the industry maintains economic competitiveness, efficiency, and acceptable financial performance. That is, firms and the industry remain 'economically fit'. The socio-political environment comprises policymakers, civil society, and social movements. Industry regimes maintain support from the socio-political environment when the industry is viewed as being 'socially fit', which is evidenced by legitimacy, a broad-based belief that an industry is socially and morally acceptable (Suchman, 1995). Legitimacy of an industry can be conferred by wider publics, social movements, and policymakers indicating legitimacy may

vary between sectors of society (Dehler-Holland et al., 2022). Over time, the diminution of legitimacy may damage public acceptance and social licence, government protection, and access to external capital (Dehler-Holland et al., 2022; Lounsbury and Glynn, 2001). These dynamics then impact on the economic environment of the industry.

Changes to industry regimes only occur after pressures emerge from both the socio-political and economic environments (Geels and Gregory, 2023). Pressures in the economic environment include changes in markets, new entrants, and supply pressures (Geels, 2014). For the coal industry, these could include competing energy technologies which have the potential to undermine markets, particularly renewable energy technologies, or technological developments aimed at maintaining the viability of coal, such as the use of carbon capture and storage technologies (cf. Brauers and Oei, 2020; Geels and Gregory, 2023). Socio-political pressures are multifaceted and encompass various legitimacy-based pressures. These include regulatory changes resulting from political or social pressures, changes in social or moral legitimacy, and changes in cognitive legitimacy (Suchman, 1995). Incumbent firms act strategically in response to such pressures to resist regime destabilisation, such as influencing actions taken by policymakers that may threaten the existing regime (Penna and Geels, 2012). Pressures often emerge in the civil society, affecting public opinions, then leading to political debates, which may result in regulatory actions and changes in the economic landscape (Penna and Geels, 2012). As such, pressures for industrial decline will first be apparent in pressures from the socio-political environment before emerging in the economic environment.

A significant aspect of managing environments is undertaken through the management of legitimacy. Pressures from the environment will manifest in the ideas and patterns of meaning attached to the industry (Osička et al., 2020) and their environments. Evidence suggests both economic and socio-political environmental pressures do become evident in discourse about the industry (Osička et al., 2020). As part of the strategic responses by the industry, pressures from the environment will initially be ignored, but eventually actively resisted (Geels, 2014). A part of this resistance entails maintaining or reshaping ideas and patterns of meaning attached to the industry to maintain legitimating narratives. As a result, discourse of the industry will comprise a complex mix of meanings ascribed by stakeholders, both supportive and critical of the industry. For example, technologies and their alternatives get imbued with various forms of legitimacy (Dehler-Holland et al., 2022; Markard et al., 2016). Discursive struggles over how the various publics think and talk about the industry affect the legitimacy of the industry, ultimately influencing public support, political action, and access to financial sources (Geels, 2010). We thus examine the discourse within three public arenas of debate as indicators of legitimacy in the economic and socio-political environments.

2.2. Agenda setting theory, discourse and TEF environments

Our use of discourse to investigate the economic and socio-political environment of coal mining stems from agenda setting theory (Dearing and Rogers, 1996; Lehotský et al., 2019; McCombs, 2005). In its original form (Dearing and Rogers, 1996), agenda setting theory stated that by selecting the objects that are reported on, the media shapes the topics that are viewed as newsworthy. The objects of the media agenda are represented in particular ways, with some attributes highlighted and others suppressed, neglected, or ignored. Through doing so, they shape public and political agendas. It is not only the content of attributes that is important in setting agendas, but the amount of coverage each is given, referred to as salience. Thus, topic share is important (Lehotský et al., 2019; McCombs, 2005). Since the original theory, agenda setting theory has acknowledged that other arenas of communication also exhibit agenda-setting effects (McCombs, 2005). Agenda setting theory thus highlights several broad agendas (Pralle, 2009) including the public agenda, the government or political agenda, and the media agenda. Topics with higher salience in the media and

public agendas are more likely to get into the political agenda (Pralle, 2009). The political agenda, also referred to as the government agenda, reflects policy making elites. The public agenda reflects opinions and agendas of the public. Public agendas can undermine social licence to operate (Hine et al., 2022); which if decreasing, may then influence the political agenda. The media agenda is in part driven by public preferences; but also mediates between political agendas and public opinion (Osička et al., 2020). The relationship between political, media and public agendas are thus complex, and comprise important aspects of the TEF environment.

Particularly relevant for the socio-political environment and potential changes thereof are discourses that are carried out in the public arena. Discourses often initially emerge in the public arena, thereby initiating socio-political pressures (Penna and Geels, 2012). Individuals and groups publicly voice their opinions and critically interact with each other about matters of interest and debate (Post, 1990). Typical important public arenas of discourse include media coverage (Buckton et al., 2019; Drewski, 2015; Raupp, 2019), political debates (Bélanger and Schimmelfennig, 2021; Söyler et al., 2023), and social media (Kou et al., 2017; Ye et al., 2017); whereby the latter allows citizens to participate in the discourse in a public sphere (Cogburn and Espinoza-Vasquez, 2011; Dahlberg, 2001). Since discourse can involve varying and sometimes conflicting content and beliefs, the constitutive elements of an issue and its boundaries can differ and change (Meyer, 1995). As such, the framing of the discourse defines the relevant elements of an issue as well as problems and solutions (Meyer, 1995). In essence, framing involves selection and salience: "To frame is to select some aspects of a perceived reality and make them more salient in a communicating text, in such a way as to promote a particular problem definition, causal interpretation, moral evaluation, and/or treatment recommendation" (Entman, 1993, p. 52). As such, framing can shape not only what is discussed but also how an issue is discussed in the context of changing socio-political and economic environments (Geels, 2014).

2.3. Decline and framing of coal industries

Destabilisation of industry regimes occurs through framing of the discussion of the industry across multiple dimensions, including economic, socio-political, and socio-cultural factors (Lowes et al., 2020; Markard et al., 2021; Rosenbloom, 2018; Turnheim and Geels, 2012). Likewise, an industry regime can be stabilised through technological innovations and sustainable developments that mitigate impacts of coal mining on the environment (Brodny and Tutak, 2022), thereby affecting how the industry is being framed across multiple dimensions. The decline of coal industries has been studied in multiple countries, including Canada (Rosenbloom, 2018), Japan (Trencher et al., 2019), the UK (Brauers et al., 2020; Isoaho and Markard, 2020; Turnheim and Geels, 2012), and Germany (Brauers et al., 2020; Markard et al., 2021). Those studies demonstrate that the decline of coal industries is a multidimensional phenomenon, involving a complex process of different pressures and dynamics interacting.

In the UK, coal industry regimes were challenged when both economic and socio-political pressures aligned (Turnheim and Geels, 2012). While economic pressures dominated in their impact on industrial decline, legitimacy was also eroded by socio-cultural and political pressures (Turnheim and Geels, 2012). Turnheim and Geels (2012) conclude that social pressures, such as due to environmental issues, may not have large effects in isolation, but they can affect industrial decline when expressed in combination with economic factors. Prior literature on the decline of coal industries also emphasises the role of policy and government. Without their willingness to act upon a coal phase-out, it is unlikely that a transition will occur (Diluiso et al., 2021). As expressed in the TEF literature (Geels, 2014; Penna and Geels, 2012), policy actions and resulting changes can be initiated through increased pressures from the public within the socio-cultural environment. However, such dynamics can take a long time to exhibit any effect (Turnheim and Geels,

2012). Within the socio-cultural environment, framing of coal with health debates has also been shown to diminish support for coal in both the UK (Isoaho and Markard, 2020) and Canada (Rosenbloom, 2018).

Previous literature has relied on media articles and parliamentary debates and documents to analyse the decline of coal – such as in the case of Germany. Similar to studies in other jurisdictions, this research reveals shifts in the framing of the industry over time. Analysing newspaper coverage of the German Renewable Energy Act, Dehler-Holland et al. (2021) found that most framing concerned the industry and thereby had an economic focus, with only a small proportion of topics framed around environmental issues. In an analysis of parliamentary debates in Germany, different categories of topics emerged, with economic topics dominating the framing of debates until after lignite production had diminished. Only then environmental topics grew to dominate (Müller- Hansen et al., 2021). Incumbents resisted regime destabilisation on the basis of security of supply of energy, regional economic outcomes and jobs in both Germany (Müller- Hansen et al., 2021) and Japan (Trencher et al., 2019).

While some research has empirically examined the framing of coal mining in other countries, there has been relatively little examination of the framing of the Australian coal industry, despite Australia being one of the largest global coal producers and exporters (Gibbons, 2023a, 2023b). One study (Stutzer et al., 2021) focused narrowly on news media and social media representations of one specific coal mining project: the Adani mine in Queensland. Within the media, economic topics dominated, particularly in the corporate oriented newspaper. In the public media organisation, environmental topics were as frequent. Despite the social media analysis demonstrating a shift away from corporate framing, the authors questioned the ability of public opinion to overcome the political economy of coal in Australia. Thus, similar to Turnheim and Geels (2012), the authors concluded the economic framing of the industry is dominant in maintaining stability of the regime, and substantial socio-cultural public opinion is required to destabilise the regime.

In this paper, we attempt a comprehensive analysis of the discourse and framing of coal mining, examining three arenas of discourse concurrently: Parliamentary debates and documents, news media articles, and social media tweets. We undertake topic modelling to inductively identify salient topics in the three arenas of discourse and categorise these topics into emergent themes. We then link those themes to economic and socio-political environments, according to the TEF framework (Geels, 2014). In doing so, we establish the relative salience by which coal mining is framed within economic terms or within socio-political concerns and examine the degree to which this framing has changed over time within and across the different arenas of discourse.

3. Methods and data

This section describes the methodological approach of this study, outlining how data was compiled and analysed. We rely on natural language processing to capture and pre-process textual data – and then, as our main analytical approach, analyse the data using topic modelling, a form of natural language processing (Jordan and Mitchell, 2015). In essence, we capture transcripts of political debates and parliamentary documents, media articles, and social media posts about coal mining in Australia, extract salient topics within this contextual constraint, and analyse how their prevalence and co-occurrence have changed over time. We chose topic modelling for several reasons. Firstly, topic modelling allows the analysis of large amounts of qualitative, textual data that would not be feasible for human coding (Crowston et al., 2012; Schmiedel et al., 2019). Secondly, topic modelling allows to inductively analyse large amounts of data without the need to predetermine categories or constructs, facilitating the exploration of latent themes (Schmiedel et al., 2019). As such, thirdly, the chosen technique can assist with discovering information and associated structures that may be missed by human analysts (Afolabi and Uzor, 2022; Meaney et al.,

2023). Fourthly, topic modelling has the ability to structure and categorise qualitative data over extended timeframes to identify trends (Afolabi and Uzor, 2022). And finally, topic modelling has been argued to be suitable for discourse analysis, aligning to its ontological and epistemological stances (Jacobs and Tschötschel, 2019). Fig. 1 exhibits the research framework that outlines high-level steps for data collection, topic modelling and analysis. The following sub-sections present a detailed outline of the research process.

3.1. Data sources and pre-processing

This study relies on multiple data sources as proxies for the public discourse on coal mining in Australia. Building upon other studies investigating public discourse (e.g. Kleinke and Avcu, 2017; Müller-Hansen et al., 2021; Weitzman and Bailey, 2019), we base our analysis on three arenas of discourse: We capture political debates, media coverage, and social media posts. In particular, we collected (1) parliamentary debates and documents from the Parliament of Australia, (2) news articles published by the Australian Broadcasting Corporation (ABC), and (3) tweets published on the microblogging platform Twitter.[1]

3.1.1. Parliamentary debates and documents

We used the Parliament of Australia's public archive[2] to search for relevant transcripts of debates and other relevant documents. In particular, our search comprised the Hansard of the House of Representatives and of the Senate, as well as committee reports and transcripts. We started with a broad search covering the terms 'coal mine', 'coal mines', 'coal mining', 'coal miner', and 'coal industry'. Our search covered the period from January 1990 to October 2022. In total, we obtained 4392 search results. After removing results for which full text documents were not available, our database included 4066 documents. Downloaded documents were either in PDF or HTM file format; using Python scripts we parsed the documents to only obtain the raw text.

Since some of the documents were of extensive length, covering multiple unrelated topics (e.g. long transcripts of a sitting, or draft bills), we reduced the noise this would add to the analysis by extracting only paragraphs in which the term 'coal' is present. This reduced our sample to 4018 documents. Upon inspection of the data, we found that some entries were mere procedural notices. To eliminate this noise from the dataset, we removed all documents with a length of less than 14 words (the cut off was decided based on manual inspection of documents) – thus, only retaining substantial text paragraphs in our dataset. After removing duplicates and further procedural documents without meaningful content, we retrained a sample of 3145 documents for the analysis.

3.1.2. Media coverage

As a proxy for media coverage on coal mining in Australia, we captured articles published by the Australian Broadcasting Corporation (ABC). We used the search function of the ABC News website[3] to identify articles containing the terms 'coal' and 'mining', retrieving 11,822 news articles published between March 2003 and August 2022. Using Python scripts, we parsed the HTML files to eliminate all HTML codes, retaining only the respective raw full text, title and publication date. Upon manual inspection of documents, we found that some articles only marginally covered the topic of coal mining. To reduce noise, we only kept articles in which the term 'coal' appeared two or more times, reducing our dataset to 7278 news articles.

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[1] Data was collected prior to the platform Twitter being renamed to X. As such, we chose to use the name Twitter in this article.

[2] https://parlinfo.aph.gov.au

[3] https://www.abc.net.au/news
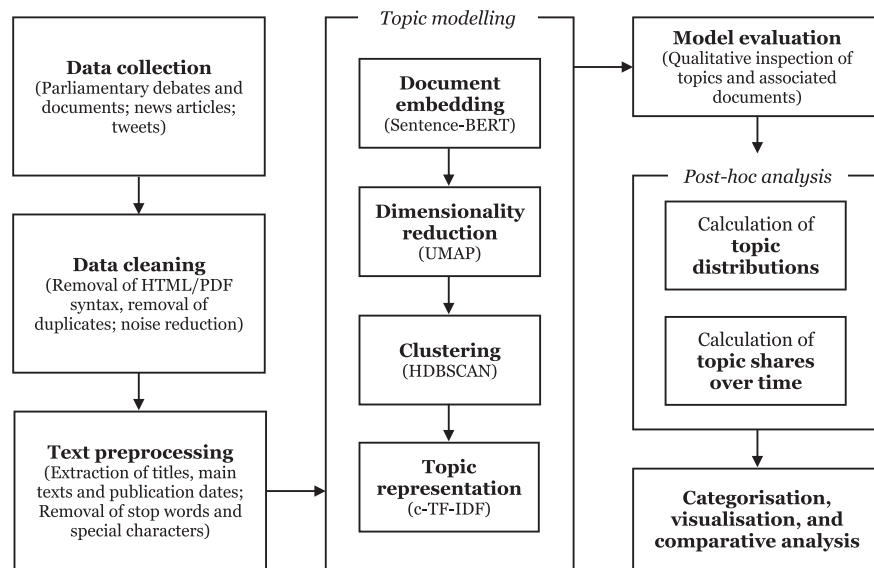
Fig. 1. Research framework for data collection, topic modelling and analysis *Note*. This figure outlines high-level steps and processes. Please also note that for each of the three data sources a separate topic model was fitted.

3.1.3. Twitter tweets

We used Twitter tweets as our proxy for capturing issues the broader public is concerned with. Via an application programming interface (API) provided for academic research,[4] we queried the Twitter archive fetching tweets containing the term 'coal' in combination with either 'mining', 'mine', 'mines', 'miner' or 'industry'. We limited tweets to those with a geolocation tagging of Australia, since this is our research context. Our search spanned the timeframe from the launch of the microblogging platform in 2011 until August 2022. After removal of duplicates, our database contained 13,235 tweets for further analysis.

In summary, we have collated a comprehensive manifestation of the public debate on coal mining in Australia, representing relevant key channels through which issues are being voiced and debated. This covers the political debate, media reporting, and voices of the broader public. In total, our three databases for analysis contain 23,658 unique documents and thereby manifestations of the public discourse, covering a timeframe of more than 30 years.

3.2. Topic modelling

The core of our analysis is the extraction of topics framing the public discourse on coal mining. Since we work with a large amount of unstructured textual data, we approached this task by using topic modelling techniques. Topic modelling is a group of machine learning algorithms suitable for natural language processing tasks (Egger and Yu, 2022). An advantage of this technique is that unsupervised approaches do not require prior labelling of the data – such as pre-specifying topical categories to which data and documents are then matched (albeit the latter is also possible). Instead, the algorithm 'learns' from the data it 'sees' and generates topics that emerge from the data. Popular and frequently used approaches to solve topic modelling tasks include Latent Dirichlet Allocation (LDA) and Non-Negative Matrix Factorization (NMF) (Albalawi et al., 2020). LDA is a generative probabilistic model assuming that each document contains a mixture of topics, whereby topics are a distribution of words (Blei et al., 2003). NMF is a clustering algorithm, factorising a document-term matrix into a document-topic matrix and a topic-term matrix (Chu and Plemmons, 2005; Suri and Roy, 2017). Both algorithms, however, have weaknesses, such as that

they follow a 'bag-of-words' approach neglecting the sequential order and semantic similarity of words in a document, and they require an a-priori specification of the number of topics present in the corpus of documents (Ailem et al., 2017; Egger and Yu, 2022; Jeon et al., 2023). More recent algorithms, utilising advances in deep learning and neural networks, assist with overcoming these drawbacks and have shown promising results with generating more meaningful topic representations (Jeon et al., 2023).

Therefore, we fit our topic models utilising BERTopic (Grootendorst, 2022). BERTopic is a topic modelling technique leveraging text embeddings. Unlike a 'bag-of-words' approach, embeddings represent words, sentences, or documents as vectors in a multi-dimensional space, where semantically similar vectors are located within spatial proximity (Egger, 2022; Egger and Yu, 2022). As such, BERTopic embeds documents in a vector space assuming that documents representing the same topic are semantically similar (Grootendorst, 2022). The technique utilises the Sentence-BERT framework (Bidirectional Encoder Representations from Transformers) to convert text into vectors building upon pre-trained language models (Grootendorst, 2022; Reimers and Gurevych, 2019). In essence, semantically similar documents represented by vectors would be closer to each other in the multidimensional space than less similar documents. After converting text into embedding representations, their dimensionality is reduced and they are clustered – a cluster of documents then represents a topic (Grootendorst, 2022). Finally, the importance of words in a cluster – that is, characteristic words for a topic – are calculated through a class-based variant of the TF-IDF (term frequency – inverse document frequency) procedure (Grootendorst, 2022). In essence, c-TF-IDF estimates the importance of a term for characterising a topic, based on its frequency of occurrence within the topic, relative to its occurrence in the entire corpus of documents.

Since our data originates from three different sources, we track the emergence, prevalence, and development of topics within these three different sources, allowing us to observe what topics have been present in political debates, media reporting, and social media posts. We therefore train three independent topic models – one for each data source. The approach to training each model is essentially the same. However, differences in data sources and topic modelling are reflected by varying text pre-processing approaches and hyperparameter tuning.

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[4] https://developer.twitter.com/en/products/twitter-api/academic-research

3.2.1. Text pre-processing

Text pre-processing involves, for example, changing all words to lower case, removing stop words or stemming and lemmatising words (Hickman et al., 2022). Unlike LDA or NMF approaches, BERTopic requires less or no pre-processing of text (Grootendorst, 2022; Jeon et al., 2023). The algorithm utilises embeddings and transformer models, for which it is important to keep the original structure of the textual data (Egger and Yu, 2022). Stemming or lemmatising words would therefore not be appropriate since it risks reducing the performance of the model (Egger and Yu, 2022; Medvecki et al., 2024). However, basic pre-processing can assist with the quality of the obtained model. We therefore experimented with different approaches to text pre-processing and their impact on model outputs and decided to remove stop words across all datasets. Stop words are common words (for example, 'and', 'the', 'a') that usually do not carry a specific meaning within a corpus (Hickman et al., 2022). We used NLTK's (Natural Language Toolkit) English language stop words list (Bird et al., 2009), and extended this list by a small number of custom stop words. Since Twitter tweets are much shorter documents including additional 'noise', we added further pre-processing steps for this data source, such as removing hashtags, URLs, and the at sign. We fed the removal of stop words as a parameter into scikit-learn's CountVectorizer to transform text into vectors (Pedregosa et al., 2011). We also specified n-grams with a range of (1,2) in this step, thereby including unigrams and bigrams (e.g. 'Hunter Valley'). After pre-processing, our documents essentially contain raw text, without any special characters, stop words or HTML tags.

3.2.2. Fitting the topic models

For each of the data sources, we fitted a separate topic model utilising BERTopic V0.14.1 (Grootendorst, 2022). Firstly, we transformed documents to embeddings creating representations in a vector space of semantically similar documents. This step builds upon the Sentence-BERT (SBERT) framework (Reimers and Gurevych, 2019). We utilised the pre-trained sentence transformer model *all-mpnet-base-v2*.[5] The model is a general-purpose model fine-tuned with more than 1 billion textual pairs (Jayanthi et al., 2021; Reimers and Gurevych, 2019). As a second step, BERTopic uses UMAP to reduce the dimensionality of document embeddings (Grootendorst, 2022). UMAP (Uniform Manifold Approximation and Projection) V0.5.3 is a dimensionality reduction technique for machine learning, preserving more of the local and global features of high-dimensional data (Grootendorst, 2022; McInnes et al., 2018). For all our three topic models, we used *cosine* as the metric to calculate distance, but varied other parameters across the three models to account for variations in the nature of the datasets. In particular, we followed a manual tuning process to fit a series of models with different combinations of the *n_neighbors*, *n_components,* and *min_dist* parameters.[6] These parameters control the local versus global structure in the data, determine the number of dimensions in the reduced space, and how closely points are located together (McInnes et al., 2018). In a third step, documents were clustered using the clustering algorithm HDBSCAN (Hierarchical density-based clustering of applications with noise) V0.8.29 (Campello et al., 2013; Grootendorst, 2022). We used *Euclidean* as a metric to calculate distance, *Excess of Mass* as a cluster selection method, and experimented with different *minimum cluster sizes* for each of the data sources and models to extract meaningful topic representations.[7] Again, we employed a tuning process fitting a series of models with various increments of the *minimum cluster size* parameter. Altogether, we experimented with different values and combinations for

each of the UMAP and HDBSCAN parameters, cross-tabulated variations of models, and inspected the model outputs in terms of the coherence and meaningfulness, as well as the diversity of topics.

After several iterations of parameter tuning, we obtained a final fitted topic model for each of our three data sources. The topic model produces a set of topics with associated terms and their c-TF-IDF scores. These terms are representative of a topic and help with further interpretation. Each of the models also contains an outlier topic (labelled as −1) accumulating noise which is typically ignored for further interpretation. During the process of parameter tuning and deciding upon a final model for each of the data sources, we validated the meaningfulness and quality of the models. We chose qualitative evaluation methods since "the interpretation of a topic as a meaningful unit remains the task of the analyst" (Jacobs and Tschötschel, 2019, p. 478) and different indices can lead to different conclusions and may not select models that align with human judgement (Meaney et al., 2023). As such, we qualitatively examined words and associated documents, coherence of the generated topics and divergence between topics, as well as the interpretability of models (Schmiedel et al., 2019). This iterative process within the research team allowed to establish face validity, ensuring that the models and topics extracted are relevant for our study context (Schmiedel et al., 2019). Inspecting documents allocated to each of the topics also assisted us with labelling the topics and capturing the core content (cf. Dehler-Holland et al., 2022; Müller- Hansen et al., 2021; Weiss and Nemeczek, 2021). We did this for each of the three topic models. In a next step, we allocated topics to higher level categories to group related themes. As such, for each of our three data sources, we obtained a representation of categories and associated topics.

3.2.3. Topic distributions

Each of the three models assigns a document to one cluster and thereby to one single topic. However, it is unlikely that one document only contains a single topic; rather, a document may contain a mixture of topics. For example, a media article may report about *reduction of mining jobs* due to *coal mines closing* amid *climate change* concerns. We therefore added a post-hoc step to our analysis. Using BERTopic, we calculated the approximate topic distributions. For subsets – i.e. a series of words – of each document, the c-TF-IDF representations and their similarity to the generated topics are calculated. This results in a topic distribution for each document with an approximated weighting of each topic contained in a document. For example, a document may be a mixture of topics x (0.5), y (0.2), and z (0.3). We varied the parameters for calculating topic distributions across our three models to account for differences in the nature of the textual documents, such as short tweets versus longer parliamentary documents. As an outcome, for each of our three data sources, we obtained a matrix with all our documents, and weightings to what extent topics are contained in a document. We excluded topic allocations falling under a threshold of 0.1, thereby ignoring marginal representations of a topic within a document (cf. Müller- Hansen et al., 2021). Using topic distribution scores, we calculated the prevalence of topics over time and visualised these dynamics with ridgeline plots. Following Müller- Hansen et al. (2021), the prevalence was standardised as the proportion of all topics in a time bin (a year in our study) accounted for by each topic in that year. These statistics are referred to as topic share in the results. Topics were allocated to categories on the basis of inspection of the main terms of each topic, along with reading documents with a range of topic probabilities. On this basis, topics with similar content were allocated to categories. These categories in the main reflect TEF categories, either economical or sociopolitical in focus. Category co-occurrence was defined as the proportion of documents that contain topics indicative of both TEF categories within the same document. TEF category co-occurrence over time was visualised using lowess plots. Statistical differences among three discourse sets of the distribution of TEF categories over time were analysed using logistical regression and visualised using predictive margins. These analyses were undertaken using Stata V18.0.

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[5] https://huggingface.co/sentence-transformers/all-mpnet-base-v2

[6] These parameters affect dimensionality reduction. We also specified a random seed to allow for reproducibility. For more details on the parameters, please refer to https://umap-learn.readthedocs.io/en/latest/parameters.html

[7] More detailed information on the clustering algorithm can be accessed via https://hdbscan.readthedocs.io/en/latest/index.html

4. Topic modelling results

In the following sub-sections, we report the results of our data analysis, describing the output of each of our three topic models. First, addressing RQ1, for each discourse frame, we describe the topics generated and our manual classification of these topics into inductive categories, and into the two TEF categories. Second, focusing on RQ2, we present visualisations of topic share and co-occurrence of the TEF categories over time to show how these have changed, an indicator of shifting framing which is of theoretical relevance to industrial decline. Third, we examine the co-occurrence of the two main topic categories, **Environment** topics and **Economy & Industry** topics, and how this has changed over time. This provides more evidence of how topics are framed in relation to other topics. Fourth, addressing RQ3, we present the results of our quantitative analysis of how the three arenas of discourse differ. Due to the complexity of the models, we focus on the most relevant data and present more detailed output in the Appendix. Implications of the model outputs are then discussed in the subsequent section.

4.1. Parliamentary debates and documents

Our fitted model extracted 17 topics from the parliamentary dataset, excluding the outlier topic (Topic −1) containing noise. We grouped these topics into 6 higher-order categories of which three, following the TEF framework, concerned the economic environment (**Economy & Industry; Industrial Relations; Technology),** and three concerned the socio-political environment (**Environment; Politics;** and **Coal Seam Gas (CSG))**. All identified topics with their respective top terms and a brief topic description, organised by topic categories and TEF categories, are listed in Appendix A, Table 1.

4.1.1. Topic and category share

The topic shares of the 17 parliamentary topics are shown in Fig. P1. The topic shares displayed in the figure represent the percentage of all topics accounted for by the topic or category. In other words, the higher the topic share, the more dominant a topic is. Ten topics were related to the economic environment, accounting for 65.8 % of total topic share in the parliamentary data. The socio-political environment comprised seven topics and accounted for 34.2 % of total topic share. The unbalanced occurrence of economic versus socio-political topics suggests a dominance, on average, of economic discussion within the parliament.

The ten topics related to the TEF economic environment reflect the dominant framing of coal mining within parliamentary discussions and reports in economic terms. The largest topic was thermal coal exports (Topic 6) describing the size and economic contribution of coal exports for the Australian industry and economy. This topic alone accounted for more than a quarter of the TEF economic environment, and for 17 % of overall parliamentary topic share. Related topics specifically discussed the role of infrastructure for coal mining (T11) and ports for exporting coal (T14). Another major topic within the TEF economic environment concerned the importance of the coal industry for employment and job creation (T1). The salience of these topics underlines the dominance of discussions about coal mining in parliament in terms of coal as an important contributor to the national economy through exporting and creating employment opportunities. Further salient economic environment topics concerned incumbent fossil fuel technologies: Coal-fired power stations (T9) and carbon capture and storage (T13). The latter reflects views and debates in the political discourse about maintaining the use of fossil fuels since CO2 emissions could be captured and stored. Conversely, renewable energy in the context of the coal industry (T5) has received relatively little attention in parliamentary debates and documents.

In contrast to the TEF economic environment topics, topic share of the socio-political topics was more evenly distributed across the topics. Most of the socio-political topics concerned environmental issues, albeit they were only reflected in moderately sized topics. These focused on climate change and climate change debates (Topics 7 & 16), and specific legislative policy responses to climate change, particularly the Carbon Pollution Reduction Scheme (CPRS) (T12) and the Clean Energy Bill that included a fixed price on carbon, commonly referred to as a carbon tax, announced and legislated in 2011, coming into effect in 2012, and repealed in 2014 (T2). One large coal mining project, the Adani mine in the state of Queensland (T8), emerged as its own topic within parliamentary debates, reflecting its contested planning and approval process in light of environmental and community concerns. Although the specific focus of environmental debates has shifted from specific policies to a specific mining project or climate change in more general, environmental framing played a dominant role within the socio-political TEF
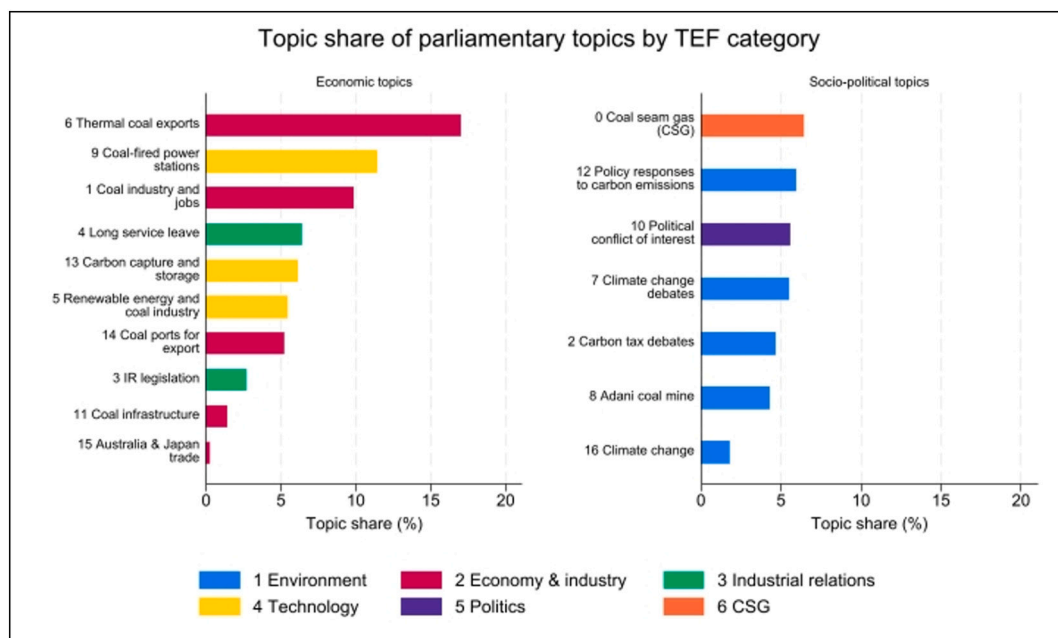

Fig. P1. Topic share of parliamentary topics by TEF category.

category. However, environmental framing in parliament rarely took a larger topic share than economic concerns.

Fig. P2 shows the relative share of socio-political and economic environment topics in the parliamentary data over time. As such, the figure displays if, when and to what extent one of the two topic categories dominates over the other. With two exceptions, economic TEF topics clearly dominated the discourse within parliament apart from two periods of increased prevalence of socio-political topic share. The first period occurred in the late 1990s, when politics became a focal concern that was reflected in the first peak in socio-political environment debate. Commencing in 2007 and lasting until 2015, the second, longer and more pronounced period of socio-political concerns occurred. These debates concerned increased discussion of community concerns about the expansion of the CSG industry coupled with a persistent increase of environmental concerns, particularly climate change. This period of socio-politically oriented debate occurred in the context of the introduction of heavily contested climate focused policy and legislation into parliament. Other than these two brief periods, parliamentary debate comprised an economic focus. In the main, these economic discussions debated the coal industry in positive terms, reinforcing the economic contribution of the industry to the Australian economy. Although socio-political debates briefly surpassed the economic topic share, the latter quickly re-emerged as the dominant category of debate.

4.1.2. Category co-occurrence

Not all documents and debates in our data concern exclusively the economic or the socio-political environment. The two TEF categories co-occurred within 40.4 % of parliamentary documents. However, documents with socio-political topics co-occurred much more frequently with economic topics than vice versa. When examining those documents that contained socio-political topics, on average, 70.1 % also included an economic topic, and only 29.9 % exclusively discussed socio-political issues. In contrast, socio-political discussion occurred, on average, in only 54.5 % of documents that contained an economic topic. In 45,5 % of documents that contained economic discussion, only economic discussion occurred with no coverage of socio-political issues. This suggests that socio-political topics were rarely discussed on their own, but predominantly also contained economic issues. In contrast, economic issues were frequently debated without any socio-political framing.

This average amount of category co-occurrence was not stable across time, as shown in Fig. P3. The figure visualises how co-occurrence of the two TEF categories has changed over time. Looking first at those documents that contained an economic topic (left-hand pane of Fig. P3), the co-occurrence of socio-political discussion with economic topics occurred in approximately 40 % of documents until the early 2000's before increasing during the late 2000s, with a peak of close to 70 % in 2012. Co-occurrence then declined again by 2016. Examination of the socio-political topics (right hand pane) reveals that co-occurrence of

economic topics in documents with socio-political topics decreased in two periods: the 1990, and the 2010s. The first period reflected increased discussion of politics. The second period occurred during the period of climate debates, during which legislative policy responses were discussed. Co-occurrence fell from earlier highs of approximately 80 % of documents, to lows of around 60 % of documents in 2012. Thereafter, economic perspectives reasserted dominance.

Due to the dominance of **Economy & Industry** topics in the TEF economic environment, and the dominance of **Environment** topics in the TEF socio-political environment, we specifically examined co-occurrence between these two topic categories. Fig. P4 exhibits co-occurrences of topic categories over time. Data shows that environmental topics have consistently also included a high level of economic and industry framing within them. In contrast, economic documents initially had a relatively low level of co-occurrence with environmental topics, but the proportion of co-occurrence increased in the years around 2010, the peak climate debate years, before again diminishing to their original rate as those debates resided. This suggests that while environmental topics were consistently accompanied by economic issues, topics concerning the economy and industry included environmental issues to a much smaller degree, except during a confined period of more intense climate change debates and related policy responses.

4.2. Media coverage

From our dataset containing news articles, our model extracted 57 topics, excluding the outlier topic (Topic −1). The number of topics is considerably higher than with the two other data sources, reflecting the broader coverage of topics in mainstream news media. We have grouped the topics into 8 categories of which two concerned the economic environment (**Economy & Industry; Industrial Relations & Employment**), and five concerned the socio-political environment (**Environment; Protests; Coal mining projects & Communities; Health & Safety; and CSG**). One category (**Politics & Policy**) contained a mix of topics from both the economic and socio-political environment. A list with all identified topics, respective top terms, and a brief topic description is included in Appendix A, Table 2.

4.2.1. Topic and category share

The topic share of the 57 media topics is shown in Fig. M1. Of note is the small topic share of most topics. Media reporting of coal related topics was typically local and specific, leading to the extraction of many small topics. There were 22 topics related to the TEF economic environment which accounted for 44.3 % of total media topic share. The TEF socio-political environment comprised 35 topics and accounted for 55.7 % of total media topic share. This suggests a more balanced prevalence of economic and socio-political topics, albeit a small dominance, on average, of socio-political discussion within the media.

The by far most dominant focus of reporting in the media data within the TEF economic category was on topics concerning the Economy & Industry. They account for more than a third of overall topic share, and 80.4 % of the TEF economic environment category. These topics covered the economic and financial performance of the coal industry (Topic 16), commodity prices (T29), thermal coal demand (T7), and export performance (T31). Two topics concerned the development of port or railway infrastructure supporting coal mining (T12 & T23). Another seven topics covered the performance and development of specific mining companies. These were reports about mergers and acquisitions, company performance, or expansion plans. The exception to this pattern were the financing issues of one mine project, the Adani coal mine in Queensland (Topic 39). The mine became a dominant focus of discussions of coal mining in the mid 2010s, and reports of its funding arrangements were part of that discussion. Besides Economy & Industry topics, a much smaller share of topics reported on Industrial Relations and Employment. These concerned industrial disputes and strikes (T8), employment in the mining sector (T9), redundancies offered to workers
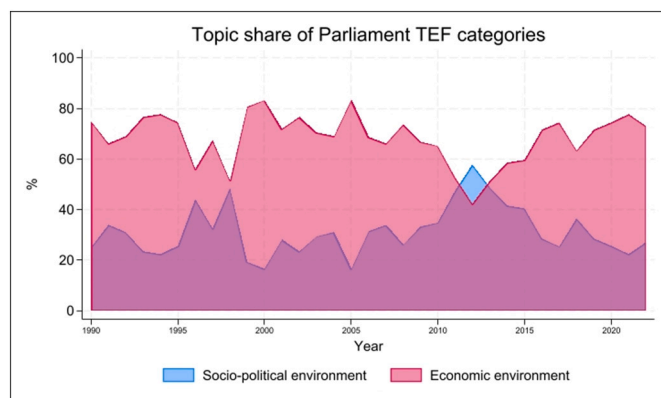

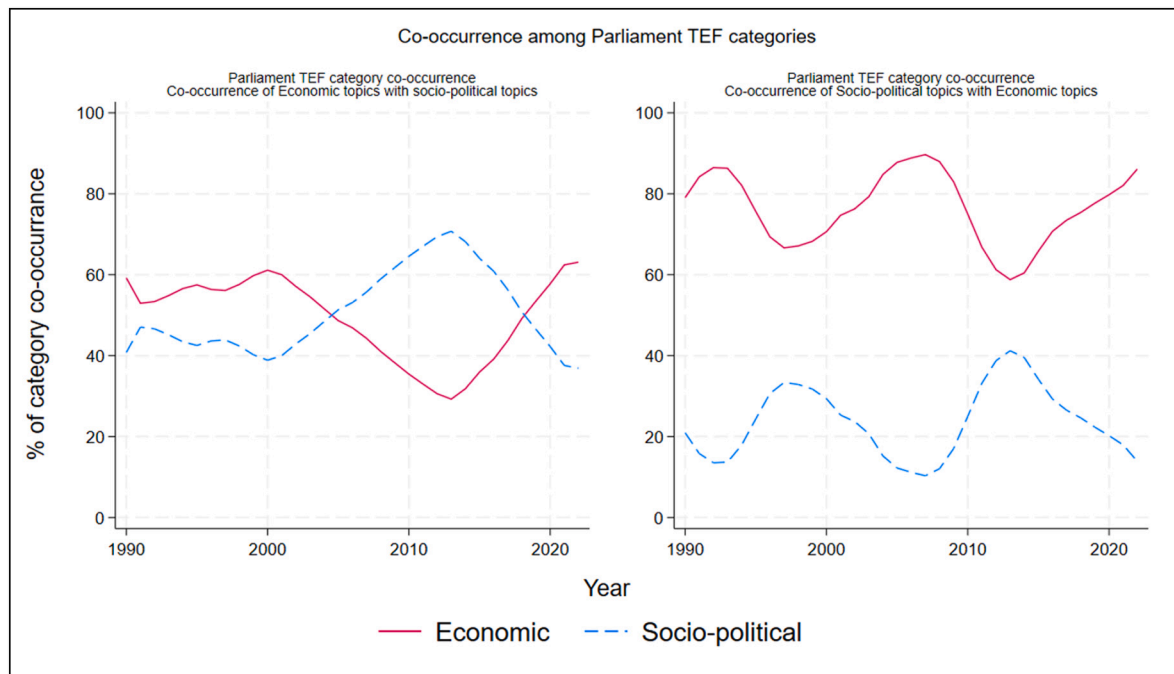**Fig. P2.** Parliament data: TEF Category topic share by year.

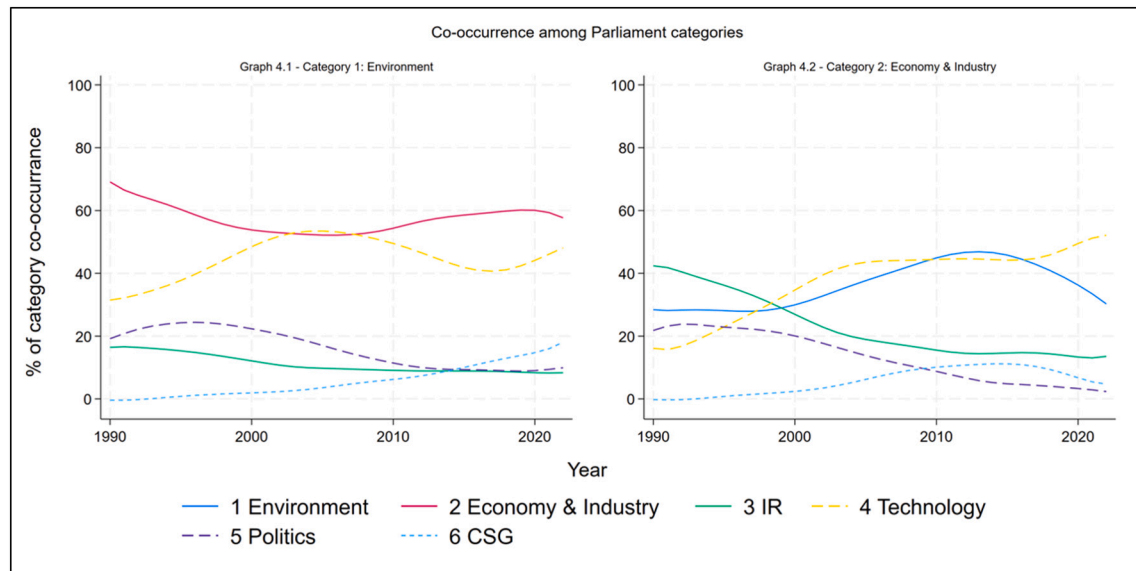**Fig. P3.** Parliament data: TEF Category co-occurrence over time.

Fig. P4. Parliament data: Co-occurrence among Environment and Economy & Industry categories.

(T15), and demand for skilled workers in the coal mining industry (T44). Only two topics within the TEF economic environment focused on economic policies affecting the coal industry. These policy discussions centred on royalty schemes and taxes related to the mining industry. Similar to what we found in the parliamentary data, economic framing of coal mining in the media predominantly focused on the performance of the industry and its relevance to the economy, including industrial relations and employment issues. The media, however, covered more local and specific issues.

Of the topics allocated to the TEF socio-political environment, a large number of smaller topics reported on local community reactions and resistance to coal mining projects (20 % of topic share, and 32.3 % of the socio-political TEF category). This includes community resistance to specific projects across Australia, land use conflicts, and concerns about

the impacts on heritage sites of traditional owners. Among these were also specific concerns about the Adani coal mining project in Queensland (T21). The second largest socio-political category comprised CSG related topics, collectively accounting for 14 % of topic share, and approximately 25.2 % of the socio-political category. Most of these topics reported on water concerns due to CSG operations (T0). Another large CSG topic was specific to the Gloucester basin region (T5) in which both coal mining and particularly coal seam gas operations were a focus of community concerns. Topics related to the environment formed only a relatively small share of the media reporting on coal mining. These topics centred on climate change (T41), carbon pricing (T4), impacts on the Great Barrier Reef (T2), concerns related to water supply (T6), water contamination (51), and effects of coal mining on flora and fauna (13). The remaining topics within the socio-political TEF environment
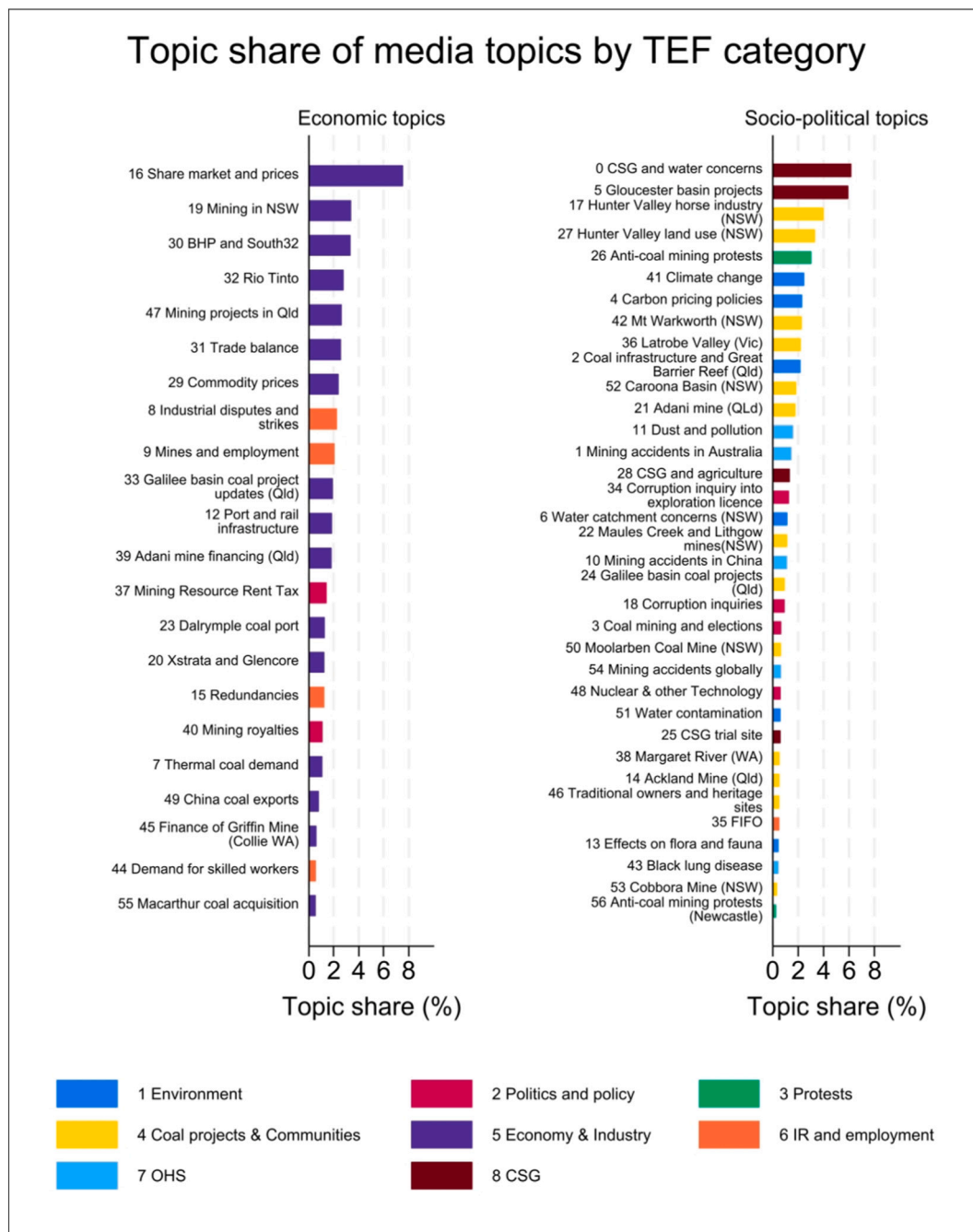
Fig. M1. Topic share of media topics by TEF category.

covered protests against the coal industry, health and safety issues, and some broader political and policy topics, a category shared with the TEF economic environment. Overall, media reporting of socio-political issues was often predominantly local and specific to particular contexts and projects.

The topic share of economic and socio-political topics over time is shown in Fig. M2. The general pattern shows the two TEF categories were mostly balanced over all years, at least in comparison with the other two datasets. Despite overall there being slightly more socio-political than economic reporting, in the very early years, there was more economic than socio-political reporting about coal. In the years 2011 to 2015, socio-political topics accounted for a larger share, compared to economic topics. This was a period of intense debate about climate change during which legislative policy responses were

discussed, a period also reflected in the parliament data.

4.2.2. Category co-occurrence

The two TEF categories co-occurred within 38.1 % of media documents, but in contrast with the parliamentary documents, documents with economic topics co-occurred more frequently with socio-political topics than vice versa. When examining those documents that contained socio-political topics, on average, 50.8 % also included an economic topic, and 49.2 % of such documents discussed only socio-political issues. In contrast, socio-political discussion occurred, on average, in 64.2 % of documents that contained an economic topic. In 35.8 % of documents that contained economic discussion, only economic discussion occurred with no coverage of socio-political issues.

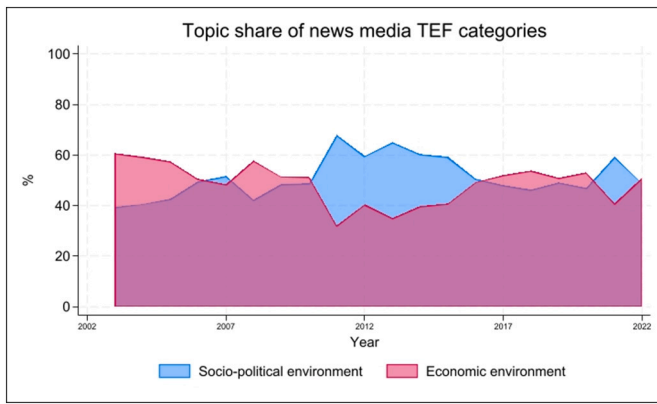This average amount of category co-occurrence was not stable across

Fig. M2. Media data: TEF Category topic share by year.

time, as shown in Fig. M3. Looking first at those documents that contained an economic topic (left-hand pane of Fig. P3), the co-occurrence of socio-political discussion with economic topics consistently increased over time, commencing with just over 40 % of documents in 2003, but reaching just over 70 % by 2022. This suggests that economic reporting on coal mining has increasingly been accompanied by socio-political aspects.

Examination of the socio-political topics (Fig. M3, right hand pane) reveals that co-occurrence of economic topics in documents with socio-political topics hovered around 60 % of documents from 2003 until 2009. The percentage of economic co-occurrence then dropped to approximately 40 % in 2012, the year in which a range of climate change measures were introduced into Australia. After the subsequent repeal of carbon pricing legislation in Australia in 2014, the percentage of economic co-occurrence increased to approximately 70 %.

As with the parliament data, we also specifically examined the co-occurrence between **Economy & Industry** topics and **Environment** topics. Fig. M4 exhibits co-occurrences of these topic categories over time. Similar to what we found in the parliament data, news media reports of environmental issues related to coal mining have consistently also included economic aspects. There was, however, a marked decrease in this co-occurrence from the mid 2000s to the early 2010s. These years

were characterized by heavily contested ideas about climate change and the role of coal. More recently, reporting of environmental concerns is again more often accompanied by economic aspects. In contrast, topics concerning Economy & Industry have a relatively low co-occurrence with environmental aspects of coal mining, albeit this has increased in the media reporting since the late 2010s. This suggests that even if environmental issues are covered, they are often accompanied by an economic framing, whereby reports on the coal mining industry and its economic impact rarely also consider environmental issues.

4.3. Twitter tweets

From our dataset containing Twitter tweets, our model extracted 22 topics, excluding the outlier topic (Topic −1). We have grouped these topics into eight categories. Two categories were related to the economic environment (**Technology,** and **Economy & Industry**) and five were about the socio-political environment (**Environment; Policy & Politics; Coal mining projects & Communities; Health & Safety; CSG).** The remaining category, **Coal mining**, although large (topic share 21.2 %) was non-informative and therefore excluded from further analysis. Identified topics, respective top terms and a brief topic description are summarised in Appendix A, Table 3.

4.3.1. Topic and category share

The topic shares of the Twitter topics are shown in Fig. T1. The two topic categories related to the economic environment accounted for 10.4 % of total Twitter topic share. The socio-political environment comprised five topic categories and accounted for 68.6 % of total Twitter topic share. This suggests a large dominance, on average, of socio-political discussion within Twitter. The excluded topic (21.2 % of Twitter topic share) comprised only short tweets, typically with the words coal and mining, and little additional content.

The two TEF Economic Environment topic categories reflected the Economy and Industry (6.25 % of Twitter topic share, and 59.6 % of the economic TEF category), and were in the main related to coal exports; and technology (4.2 % of Twitter topic share, and 40.4 % of TEF category). The larger Economy and Industry topic was Coal industry and jobs (Topic 11) with documents about the employment size of the industry. Within the topic, the coal mining industry was variably argued to be
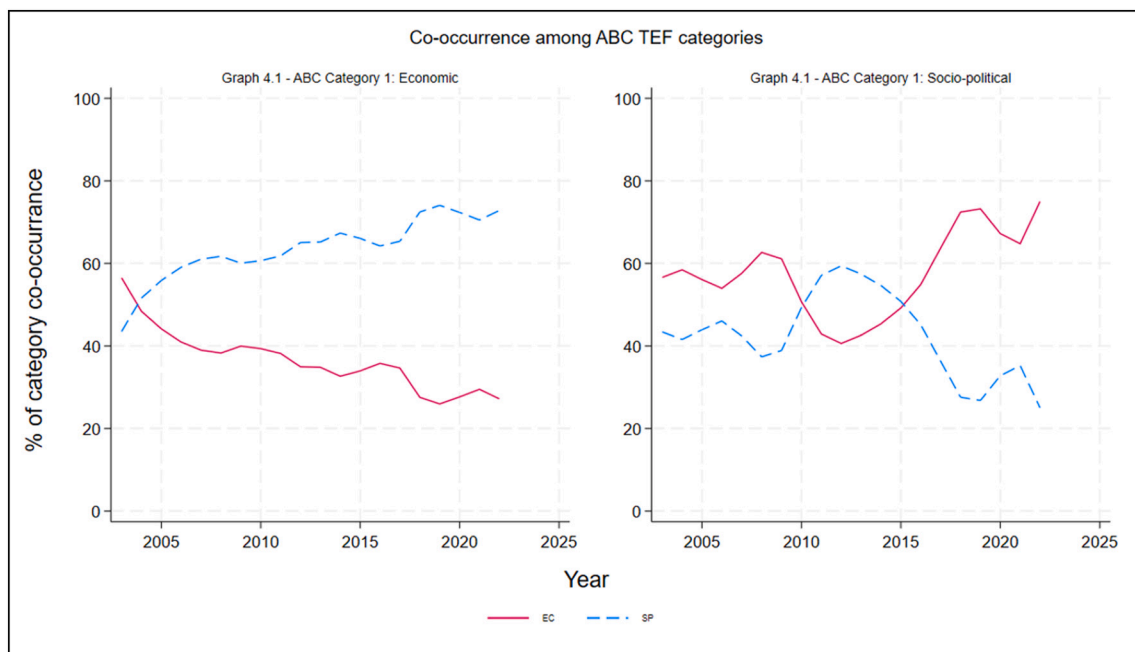

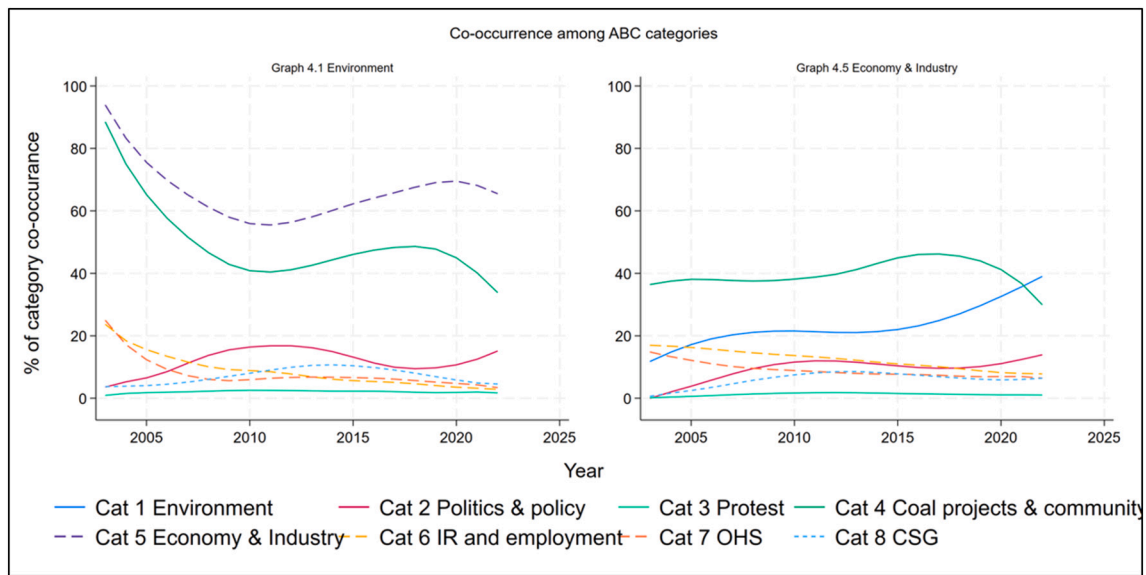**Fig. M3.** Media data: TEF Category co-occurrence over time.

Fig. M4. Media data: Co-occurrence among Environment and Economy & Industry categories.

either a large or a small employer reflecting a debate about the economic benefits of the industry. Exports to China was the focus of Topic 8, which increased in topic share from 2020, albeit still relatively small, after China imposed a ban on the import of Australian coal. The Technology topics concerned potential competing energy and renewable energy technologies. The larger topic contained positions both supportive and critical of the use of renewable energy (T7). The second, smaller topic (T20) was about a broader set of energy technologies, for example, nuclear and high energy low emission coal plants, which were compared, usually favourably, against the use of renewable energy technologies.

The socio-political TEF environment comprised five categories. Three categories had relatively large topic shares. Politics and policies (24.6 % Twitter topic share, and 36.0 % of the socio-political topics) concerned tweets critiquing political parties and their alleged close relationship with the coal industry, and critiques of coal subsidies. Coal mining projects and communities included topics about specific coal mining projects and their impact on local communities (21.1 % of Twitter topic share, and 30.8 % of the socio-political category), including discussions about specific mine approvals and court cases. Again, one mine project stood out in the debate: The Adani coal mine in Queensland (T1). Tweets about the Environment, including topics about climate change (T4), methane emissions (T16), and water contamination (T3), accounted for 18.4 % of Twitter topic share (27.0 % of socio-political topics).

Fig. T2 shows the relative share of each TEF category over time. Tweets about the socio-political environment of coal mining consistently dominated over the time, although this dominance decreased slightly after 2016. This is in stark contrast to the parliament and media data, where either economic framing predominated or was in balance with socio-political framing. Here, in our Twitter data, coal mining is distinctively and consistently framed around socio-political issues, including environmental aspects, community concerns, and debates about the politics of coal mining.

4.3.2. Category co-occurrence

The two TEF categories co-occurred within 27.7 % of Twitter tweets. Unsurprisingly, given the dominance of the socio-political category, tweets with economic topics co-occurred more frequently with socio-political topics than vice versa. When examining those tweets that contained socio-political topics, on average, 44.1 % also included an economic topic, and 55.9 % of such tweets discussed only socio-political

issues. The amount of co-occurrence of economic topics in tweets that contained socio-political topics increased over time (see Fig. T3, right-hand pane) from about 40 % to 60 % of tweets.

In contrast, socio-political discussion occurred, on average, in nearly all tweets that contained an economic topic, 88.6 %. In merely 11.4 % of tweets that contained economic discussion, only economic discussion occurred with no coverage of socio-political issues. This very large co-occurrence remained fairly stable over time, as shown in Fig. T3, left-hand pane. As such, the pattern of co-occurrence in the Twitter data differs considerably from the parliament and media data.

The differences to the parliament and media data are also obvious when specifically examining the co-occurrence between **Economy & Industry** topics and **Environment** topics. Fig. T4 exhibits co-occurrences of these topic categories over time. Environmental issues related to coal mining were rarely accompanied by economic aspects. However, there was a recent increase in environmental debates that were linked to politics and policies, possibly reflecting a more contested debate about the environmental positions of political parties. The figure also shows that there was a stable co-occurrence of Economy & Industry topics with environmental aspects, albeit on a modest level. This suggests that in our Twitter data environmental issues and concerns were mostly raised and discussed without taking economic aspects into consideration, whereby the coal industry and its economic impact was relatively often accompanied by environmental framing.

4.4. Comparison of the three data sets

The results presented so far have analysed each discourse set separately. It revealed that political discourse has been strongly framed by economic topics, emphasising the important role that coal industry and exports play for Australia. The media discourse was more balanced between economic and socio-political discourse, while the public discourse was very strongly socio-political in its framing. To test for statistical differences in discourse among the sources, we employed a logistic regression model with the number of economic topics in each year as the outcome variable and the discourse source (Parliament, Media and Twitter) as the predictors. As shown in Fig. C1 below, in the main, the media discourse contained significantly fewer economic topics than did the parliament discourse in all years except for 2003, 2004, and 2012. The lack of differences in 2003 and 2004 were due to smaller numbers of topics extracted in those years, leading to wide confidence intervals. Economic discourse was significantly less in the Twitter discourse than
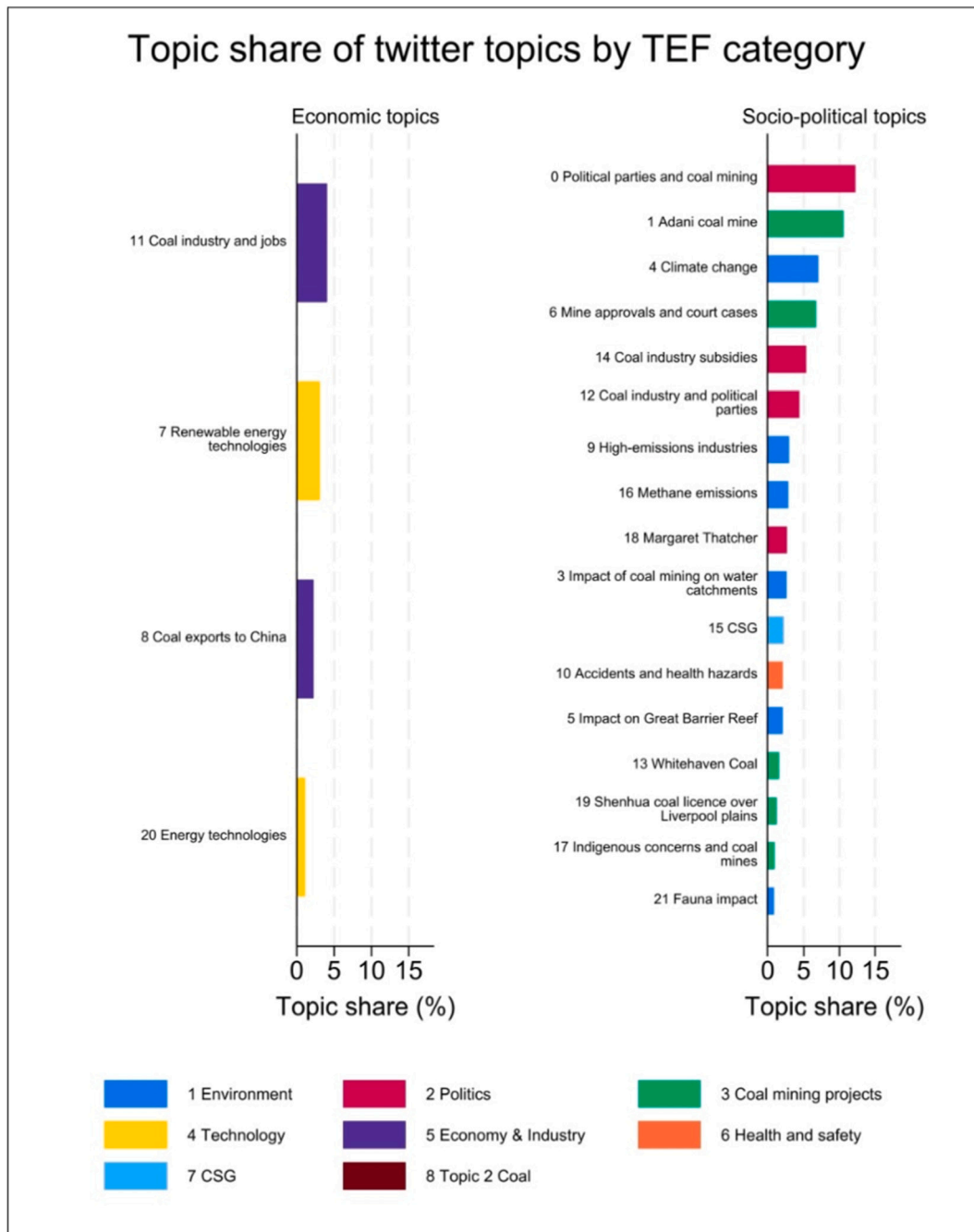
Fig. T1. Topic share of Twitter topics by TEF category.

either of the other two discourses (all significant $p < .001$).

There were some differences across years as well. Regarding the parliament discourse, there was a significant decrease in the proportion of economic topics between 2011 and 2014. Thereafter, the proportion of economic topics increased again. A similar pattern occurred in the media discourse. Together, these differences suggest some possible reasons for why coal mining in Australia has shown no decrease in apparent support. The period in which economic framing decreased, and socio-political framing increased occurred in the years of arguably the most intense climate change debates held in Australia. During this period, climate policies were enacted, and then with a change of government repealed. The new government had framed climate change issues as issues of poor economic management, and any policies as unnecessary economic burdens. The political discourse patterns reflect this dynamic clearly, with the increased socio-political debates

occurring, and then a resurgence of very strong economic framing of coal mining. The media framing also resumed a more equal distribution of topics between economic and socio-political framing, indicating less pressure for action on coal mining from within the media framing of coal mining.

4.4.1. Environmental topics

A deeper examination of the types of topics that comprised the socio-political framing adds to the story. Fig. C2 below shows the proportion of topics that were specifically about the environment, rather than other socio-political topics. In all three datasets, the absolute proportion of topic share of environmental topics is moderately low: Coal mining is discussed within a wide variety of topics, with only a minority topic share specifically related to the environment. To test for statistical differences in topic share of environmental discourse among the sources,
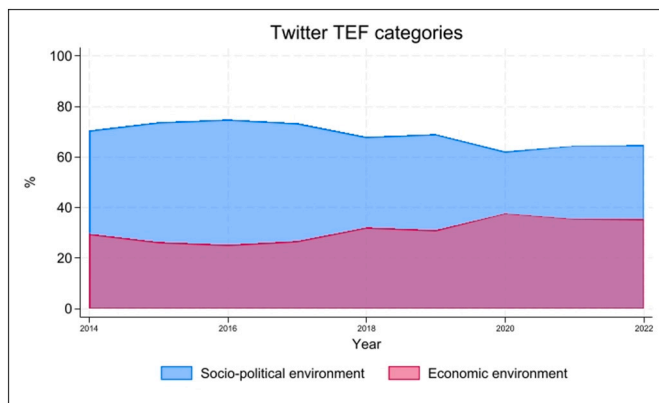
Fig. T2. Twitter data: TEF Category topic share by year.

we employed a logistic regression model using the number of environmental topics in each year as the outcome variable and the discourse source (Parliament, Media and Twitter) as the predictors. Results show that on average across the years, environmental topic share was significantly lower in the media discourse compared to the parliamentary discourse ($b = -1.65$, $p = .002$), although this difference reduced markedly to become non-significant from 2020 onwards.

During the period of climate change debates, the proportion of topics within the political discourse that explicitly linked coal mining and the environment increased. The increase commenced from 2006, as a new government campaigned on the need to address climate change, reaching a peak in 2011, accounting for nearly 37 % of topic share in that year. The proportion of environmental topic share then rapidly decreased in 2012. Media framing linking coal mining to environmental topics increased at the same time but dropped off in 2010. Topics unrelated to the environment thereafter comprised a larger proportion of the socio-political topics in the media. Discourse framing would suggest this lack of media framing could have meant there was limited pressure on policy makers to address coal mining as an environmental issue, coupled with strong economic framing of coal mining within the political discourse. Support for coal mining in these circumstances is unlikely to diminish.

In the most recent years, there was a greater convergence of the proportion of environmental topics in the three discourses. Over the summer of 2019–2020, Australia experienced extreme bushfires across large parts of the country, greatly increasing the salience of climate change. If this increase in linkage of coal mining and environmental issues continues in subsequent years across all three discourses, the legitimacy of coal mining might be destabilised. However, when the environmental salience and economic salience graphs are compared, it appears that over this same period, parliamentary and media linking of economic framing with coal mining was maintained, suggesting a destabilisation of the legitimacy of coal mining was not occurring despite the increased salience of environmental framing.

5. Discussion

Based on an extensive dataset of documents reflecting discourse and debates on coal mining carried out by policymakers, news media, and the broader public, our analysis has uncovered topics, themes, patterns, and trends over time, revealing insights into the framing of coal mining and changes thereof. We sought to answer three research questions pertaining to (1) the framing of coal mining within different arenas of discourse, (2) variances across them, and (3) changes over time. In the following sub-sections, we discuss our findings guided by our three research questions. This is then followed by a discussion of implications for the legitimacy of coal mining in the context of industry regimes and transitions.

5.1. The framing of coal mining and variances thereof across discourse by policymakers, news media and social media

Our analysis has uncovered how coal mining is framed within different arenas of discourse. Revealing the framing of a subject matter – in our case, the discourse pertaining to coal mining – uncovers what elements of an issue define the discourse (Meyer, 1995). As such, it determines what aspects of an issue are selected, are salient in communicating the subject matter, and therefore promote particular definitions, interpretations and evaluations (Entman, 1993). Our results demonstrate that in parliamentary debates and artefacts, coal mining is predominantly framed in economic terms. The economic performance of
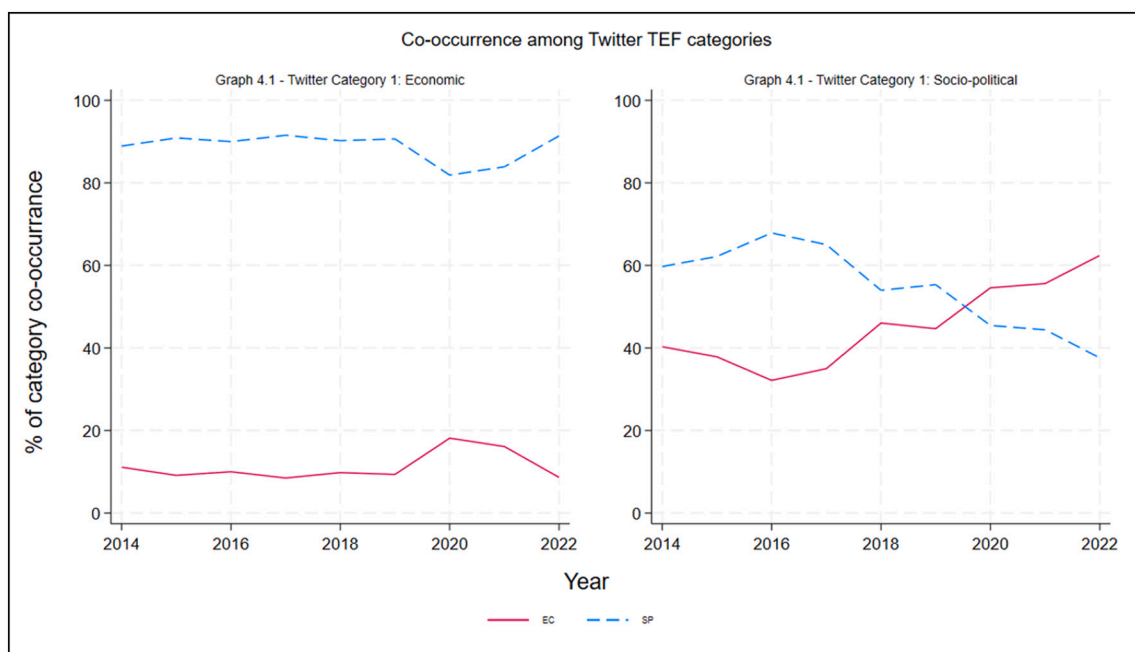

Fig. T3. Media data: TEF Category co-occurrence over time.
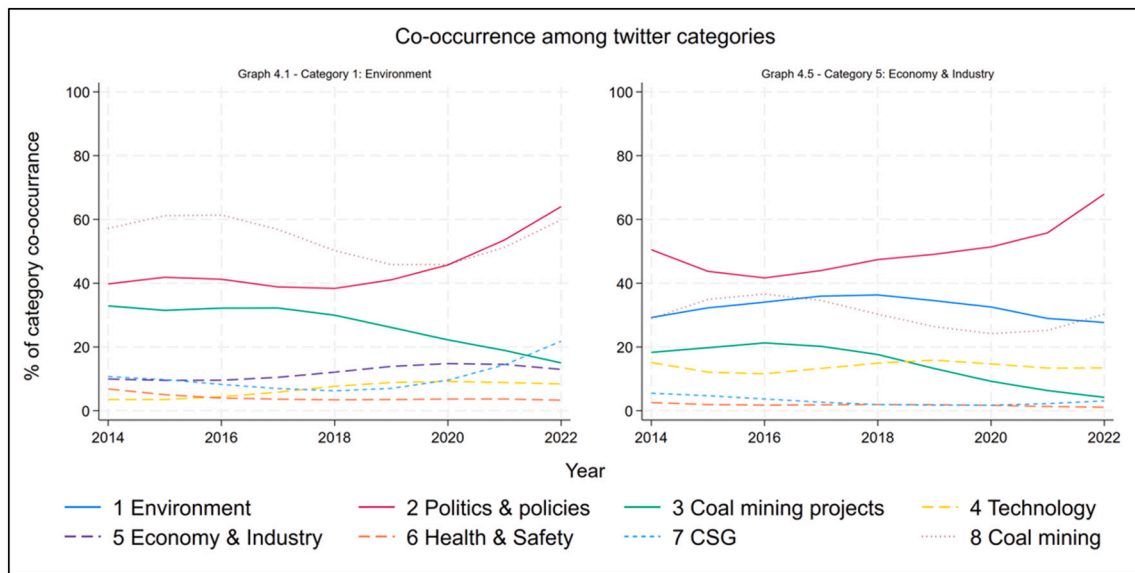
Fig. T4. Media data: Co-occurrence among Environment and Economy & Industry categories.
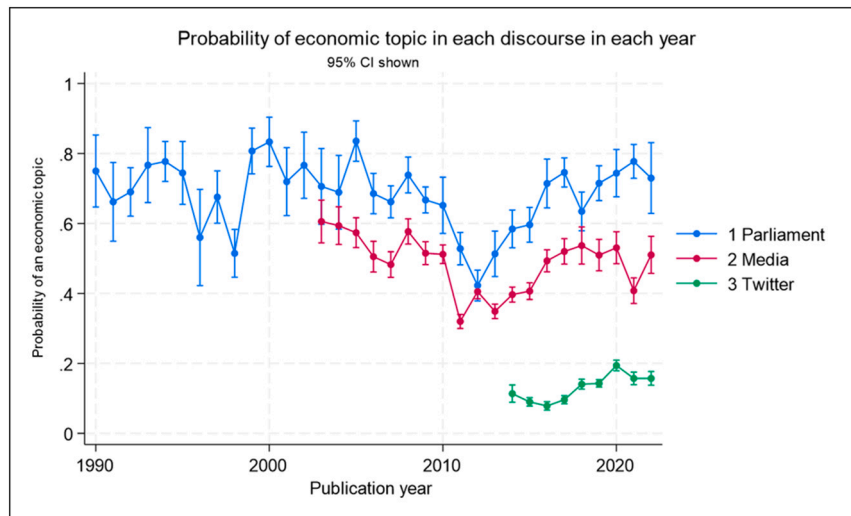
Fig. C1. Probability of economic topic in each discourse in each year.
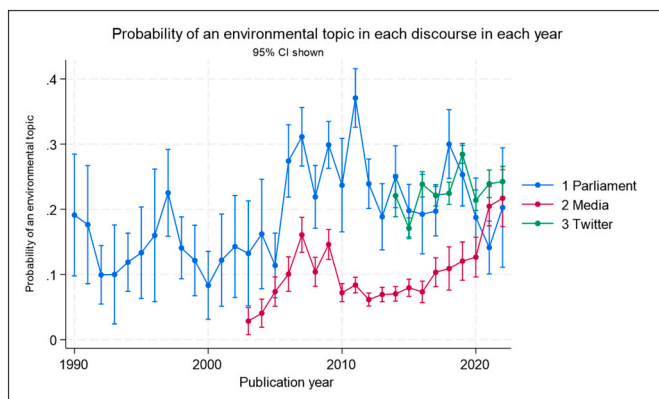
Fig. C2. Probability of an environmental topic in each discourse in each year.

coal mines and mining companies, coal as an important commodity for export, coal mining generating employment opportunities, and technologies supporting the ongoing use of power generated from coal are most salient in the discussions among policymakers. This finding is partly consistent with research in Germany where coal mining was initially framed as enabling economic growth and securing energy supply (Müller- Hansen et al., 2021). A marked difference to this prior research, however, is that we did not find a shift in the parliamentary debates towards the expansion of renewable energy and a phase-out of coal mining (Müller- Hansen et al., 2021). This suggests that, unlike in Germany and other countries, economic contributions of coal mining prevail in the political debate in Australia. While climate change dominated the socio-political framing of coal mining in parliament, overall, socio-political framing was almost consistently surpassed by economic framing. Moreover, much of the socio-political framing was accompanied by economic issues – further supporting the dominance of economic terms in promoting and evaluating coal mining. These findings have parallels in related studies, such as where economic topics dominated the debates in the German parliament (Müller- Hansen et al., 2021).

For the news media coverage of coal mining, our results suggest a different pattern. Here, the economic framing does not dominate over socio-political framing. Overall, the salience of different aspects in communicating the subject matter presents itself as more balanced (Entman, 1993). Similar to debates by policymakers, the economic performance of the coal industry and of individual coal mines, as well the industry infrastructure, define the economic framing of the discourse. The socio-political framing, however, is more diverse with a large number of small topics related to local community reactions and resistance to specific projects, as well as community concerns and land use conflicts pertaining to coal and coal seam gas projects. The more balanced selection and representation of topics in our news media data conform to the broader role of journalism in a democratic society; to contribute to the free formation of opinions by providing information on a variety of issues, supplying different opinions and scrutinising those who govern (Asp, 2007). As such, news media fulfills an important mandate as an arena of discourse by reproducing positions and opinions of various stakeholders about matters of interest and debate (Post, 1990). Consequently, the selection and salience of how coal mining is framed is more diverse in the news media data, promoting a broader range of definitions, interpretations and evaluations compared to the parliamentary data (Entman, 1993). The broader diversity of the framing of coal in the media is supported by previous research in other jurisdictions. In Canada, legitimising (e.g. coal offering reliable and affordable energy) and delegitimising narratives (e.g. coal as a climate change problem) were uncovered in the media discourse (Rosenbloom, 2018). In the UK, climate and health issues were reflected in the media, but also a narrative of coal as a reliable and affordable energy source (Isoaho and Markard, 2020). Unlike those studies, our analysis of media articles does not indicate a framing in the media discourse that suggests a decline of coal in the context of Australia.

In contrast to debates by policymakers, debates in the broader public proxied by microblogging posts concentrate on the other end of the spectrum. In our Twitter data, we observe a large dominance of socio-political framing of coal mining. Here, the public debate focuses on political parties and their positions towards and ties with coal mining, climate change, as well as resistance to specific coal mining projects – whereby posts about the Adani coal mine in Queensland stand out. The latter reflects the social movement that emerged as a response to a highly controversial coal mining project, driven by climate change concerns and critiques of government actions (Hine et al., 2022). This one mining project became symbolic for both pro- and anti-coal mining debates (Jolley and Rickards, 2020). Consequently, it is not surprising that debates were not only carried out in the form of protests on the streets, but also in an easily accessible online platform, allowing citizens to participate in a discourse in the public sphere (Cogburn and Espinoza-Vasquez, 2011; Dahlberg, 2001). Coal mining framed in economic terms was not absent in the public debate, but consistently and markedly surpassed by socio-politically framed topics and issue. Economic framing in the Twitter data centred on exports, jobs and technologies – mirroring the nature of the economic framing in parliamentary and news media data. While our data is only a proxy for opinions and salient issues shared by the broader public, it suggests that there is a discrepancy between what and how coal mining is debated in the political domain as opposed to the concerns of citizens – potentially reflecting a disconnection between politics and public (Coleman et al., 2011). Results from our analysis of Twitter tweets support earlier findings by Stutzer et al. (2021) who more narrowly focused on the Adani coal mine project. Stutzer et al. (2021) found that environmental topics have been a dominant focus, with an open debate of and salient opposition to coal mining. Our findings, however, extend beyond this one mining project and show a broader sphere of the framing of coal mining in social media posts as a proxy for debates in the public.

Taken together, the framing of coal mining in economic terms dominates the political debate, mirrored by a strongly economically focused, yet more balanced, framing in the news media where socio-political framing has an almost equal share. Debates in the broader public, however, predominantly focus on socio-political issues. This suggests that – as observed in related research – in the political sphere, coal mining is primarily defined as a contributor to the economy, whereas in the public, concerns over environmental and climate issues prevail. The media, fulfilling its role in a democratic society, reproduces a more balanced and broader range of issues and opinions, acknowledging both the economic role coal mining plays and the concerns salient among parts of the public. Relying on a broad range of data from different sources allowed us to compare and contrast between the framing of coal mining in multiple arenas of discourse, thereby extending prior work that more narrowly focused on only one arena of discourse in isolation, or on a specific mining project.

5.2. Temporal changes in the framing of coal mining

Our analysis revealed that the framing of coal mining has remained remarkably consistent over time. In parliament, economic framing consistently surpasses socio-political framing – with one exception: During a brief period between 2010 and 2015, socio-political framing dominated the debate among policymakers. These discussions primarily centred around increased environmental and community concerns and the introduction of climate focused policies. However, this shift in framing was short-lived, and soon economics were the dominant focus again. In the more balanced news media data, a similar peak of socio-political framing can be observed in the same period – reflecting growing climate change and community concerns, and coverage of related policies and legislations. Debates in the broader public, reflected by our Twitter data, did not show any notable changes over time, with socio-political framing dominating.

The consistency in the framing of coal mining suggests that the relevant elements of the issue in the discourse have remained relatively stable over an extended timeframe. As such, how coal mining has been predominately framed, has not considerably changed over time. If changes occurred, the previously dominant framing has quickly re-emerged. The stability and differences in framing between parliament data and social media data suggests a mismatch between how coal mining is viewed by policymakers versus parts of the broader public. In addition, the predominant framing in economic terms by policymakers suggests that a shift in the framing of coal mining has not occurred in Australia as of yet, unlike other countries – such as Germany – where economic framing dominated in parliament, but was then surpassed by environmental framing (Müller- Hansen et al., 2021).

5.3. Implications for the legitimacy of industry regimes and transition

The Triple Embeddedness Framework (TEF) framework (Geels, 2014) suggests that the coal mining industry in Australia is unlikely to decline until support from both the economic and the socio-political environments declines. Industries are legitimated through the narratives within these discourses, which provide both the frames in which legitimation occurs, and their relative salience. We have used the TEF to categorise topics to assist with the evaluation of the salience of the economic and socio-political environments. We found that policymakers in Australia view coal mining primarily within an economic frame, focused on export value, share prices, employment, and the contribution of coal mining to the Australian economy. Even when socio-political topics are discussed, this typically occurs within the context of an economic framing.

The persistent focus on economic framing suggests that the legitimacy of coal mining as reflected in policymakers' discourse is not under threat, or when it has been, for example when climate debates became most focused, economic framing was quickly reinstated. This may explain why previous attempts to weaken the legitimacy of coal mining in Australia that do not confront the economic framing of coal mining appear to not have much impact on the political support for coal mining.

The salience of economic and socio-political topics in the media was relatively balanced. Over time, however, the reporting of economic and socio-political topics has become less siloed, with the majority of reporting containing both sets of topics within the same report. Over time, the joint reporting of both socio-political and economic issues within the same article has increased from less than 50 % of articles to nearly 80 %. This suggests that the framing of coal mining in the media has been changing so that the economics of coal mining is increasingly integrated with socio-political topics.

Socio-political topics in the media were frequently about geographically localised issues affecting specific communities, while the economic framing was typically more focused on national or industry level issues. While a relatively large share of news media, this is in contrast to policymakers who rarely debate local concerns. A similar focus on local impact was reported by an analysis of coal mining discourse in the Czech Republic (Černoch et al., 2019). They identified a local impact frame centred on the value of community and the surrounding environment in which coal mining was discussed as a local issue. Within this frame, broader environmental issues such as climate change were not salient. We identified a very similar pattern in the media reporting, where many topics concerned individual projects and their community impacts, but rarely overlapped with broader climate change issues. Similarly to that reported by Černoch et al. (2019), topics concerning alternative power generation, such as renewable energy, were also largely absent in the media topics about coal mining, suggesting the link between coal mining and the use of coal was not a basis of the media agenda. These patterns point to an absence of some key discourses that could potentially contribute to the destabilisation of the environment for coal mining. Although unsupportive socio-political discourse in Twitter is highly salient compared to economic discourse, the public agenda identified in Twitter to date appears to have had no discernible impact on the topics and salience of discourse of policymakers.

5.4. Practical and policy implications

Our analysis of the framing of the discourse on coal mining in parliament, media and the broader public has several practical and policy implications. Practically, our findings suggest that the coal industry regime in Australia is relatively stable and has been so over the last few decades. While climate change and environmental impacts of coal mining have been debated to a varying extent in the three arenas of discourse, the coal industry does not appear to be under threat, due to economic benefits of the industry dominating the discourse. Coal mining remains supported across political orientations and by large parts of the broader public. This is in contrast to other countries, such as the UK, Japan and Germany, where political and public support for coal mining have diminished (Brauers et al., 2020; Trencher et al., 2019). In these regards, Australia appears to lag behind other jurisdictions in which industrial decline has occurred or commenced. Practically, the framing of coal as economically beneficial would need to be ruptured. While this has occurred in other jurisdictions driven by policymakers, parts of the public and diminishing economic benefits of coal mining, Australia does not appear to be on this trajectory.

The benefits of coal mining for the national economy equip the coal industry with a significant voice, contributing to political support for the industry. Thus, the economic weight and the influence of the incumbent industry regime on policymaking would need to decline for the legitimacy of the industry to decrease. This could occur through the rise of alternative industries, such as expanding renewable energy production and finding alternative export commodities replacing the dominance of coal; for example, hydrogen (Sharma et al., 2023). Likewise, policies addressing climate change and emissions that had previously been repelled would need to be reconsidered to disincentivise coal mining (Binyet and Hsu, 2024). For this to occur, however, policymakers would need to withstand pressure from industry, unions and affected coal mining communities that would suffer economically from an industrial decline. Government and policymakers in Australia could learn from other jurisdictions how to or how not to manage and govern the exit of coal mining to facilitate a just transition of affected regions (Giurco et al., 2011; Harrahill and Douglas, 2019).

5.5. Limitations and future research

The current paper has several strengths and, of course, some weaknesses. The integration of three arenas of discourse, rather than just one as often done in such analyses, allows comparison of three important agendas. This allows comparing and contrasting the framing within and between these arenas, facilitating insights into how the debate on coal mining has developed in different public forums. Furthermore, the use of a guiding theoretical perspective, the TEF, provides a consistent approach to understanding the topics that allowed direct comparison. The use of natural language processing (NLP) facilitated much larger amounts of text to be analysed which allowed temporally contained and sometimes small individual topics to be extracted, which could be classified into broader themes and TEF categories. Manual coding of such large amounts of text would have been infeasible. But of course, there are some limitations. The use of topic modelling to extract topics from a large number of documents means that the nuanced arguments that occur within topics are not easily identifiable. A topic may therefore include arguments that are both supportive and unsupportive of coal mining, making evaluations of the environment for coal mining in those terms difficult. Nonetheless, the topics were typically quite tightly confined, and the dominant arguments contained readily apparent. Since we relied on an algorithm that essentially classifies text documents into categories, there is the chance of individual documents being misclassified. However, we performed extensive manual checks and inspections and found this to be a negligible issue. Other data collection and analysis approaches – including qualitative coding and statistical analysis – likewise are prone to suffer from errors and biases. Although extensive, the data we used was also limited to one source for each of the three domains due to data accessibility. As such, the generalisability of our findings is limited due to the nature of the datasets and their geographical boundaries. The inclusion of additional media sources and public discourses could strengthen the generalisability of the results, as could the triangulation with other sources of data. However, all types of data analysis methods suffer from limitations in regard to their generalisability (Schmiedel et al., 2019).

The use of NLP approaches for analysing discourse is developing methodologically. A critique of such big data methods is the limited inclusion of theory when interpreting the results, leading to largely descriptive findings. We have attempted to address this critique by basing our analysis on the Triple Embeddedness Framework (TEF). In line with our study's objective, we used an unsupervised approach to identify emerging topics based on the underlying data. Future research could explore opportunities for supervised or semi-supervised approaches to build theoretical constructs into the NLP process. Thereby, topic modelling on a dataset could be driven by prespecified theoretical constructs. Another opportunity for future research could be an attempt to utilise topic modelling to generate new theory. This would, however, require careful integration with other approaches and methods. Empirically and contextually, future research could replicate this study in other coal mining jurisdictions – such as Indonesia, China, India or the United States – to explore aspects of the discourse on coal mining in these countries. This would also open the opportunity to more systematically compare how the framing of the discourse may differ across coal mining jurisdictions. Another interesting study would involve contrasting the framing of coal mining with how renewable energy alternatives are framed in different arenas of discourse. This could reveal interesting insights into the trajectories of competing resources and technologies.

6. Conclusion

This study sought to examine how coal mining in Australia is framed within and across multiple arenas of discourse, how this framing has changed over time, and what implications can be drawn for the support or decline of the industry regime. We found that the discourse of policymakers is dominated by economic framing, and this framing is persistent. For policy support for coal mining to decrease, our findings suggest discussion about such changes needs to occur within economic framing. To date we have no evidence of this occurring. The discourse in the broader public is mainly framed withing a socio-political lens. Socio-political framing would need to replace the dominant economic framing in parliament for coal mining to be delegitimised. It is unlikely that in the foreseeable future, public socio-political discourse will weaken the strong support of coal mining rooted in the economic discourse on the policy level. Framing of coal mining in the news media is more balanced, with economic and socio-political discourses now most frequently intertwined. Agenda setting theory would suggest that over time, these other agendas may get incorporated into parliamentary debate.

Our study makes theoretical, empirical and methodological contributions. We present an integrated theoretical framework to robustly conceptualise and analyse the framing of coal mining across multiple arenas of discourse. Building upon the Triple-Embeddedness-Framework we conceptualise the framing of coal mining as a reflection of regime stabilisation or destabilisation through the presence or absence of legitimacy in the economic and socio-political environment. Integrating agenda-setting theory, we demonstrate how the discourse in multiple arenas materialises legitimacy and its effect on industry transitions. Empirically, we go beyond analysing one arena of discourse in isolation, and instead compare and contrast multiple arenas, reflecting that legitimacy pressures are rooted in discursive debates among various publics. Contextually, we focus on Australia – an economy heavily reliant on coal mining and coal exports that has previously been neglected in similar studies. And finally, we make methodological contributions by demonstrating the utility of using natural language processing techniques in social sciences research to process and analyse large amounts of data that would otherwise remain untapped. We further apply a robust theoretical framework to a methodology that has been criticised for being merely descriptive of the topics generated, with an absence of a theoretical framework (Kar and Dwivedi, 2020). The consequence is that results become difficult to compare across studies due to idiosyncratic topic descriptions. In our study, we employ the Tripple-Embeddedness-Framework (TEF) as a theoretical framework through which we classify the topics that emerge from topic modelling. In doing so, we are better able to compare with other studies that have examined industrial decline.

CRediT authorship contribution statement

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

Appendix A

Table 1
Topics extracted from parliamentary debates and documents, with associated labels and top terms, grouped by category.

Category	Topic label	TEF	Docs (%)	Topic share (%)	Topic description	Top terms based on c-TF-IDF scores
1 Environment (TS = 22.2 %)	12 Policy responses to carbon emissions	SP	13.3	6.0	Debates about policy responses to carbon emissions and coal industry, particularly focused on the Carbon Pollution Reduction Scheme (CPRS)	coal, emissions, industry, carbon, coal industry, scheme, jobs, australia, energy, government
	7 Climate change debates	SP	12.3	5.5	Debates about responses to climate change and international obligations.	coal, energy, australia, government, emissions, power, industry, going, world, climate
	2 Carbon tax debates	SP	10.4	4.7	Debates around the carbon tax which was introduced in 2012.	carbon, tax, industry, carbon tax, price, opposition, government, coal, leader, leader opposition
	8 Adani coal mine	SP	9.6	4.3	Impact of mining on the Great Barriers Reef, with a focus on the Adani coal mine.	reef, adani, coal, mine, galilee, carmichael, galilee basin, queensland, basin, barrier reef
	16 Climate change	SP	3.9	1.8	Debates about climate change.	climate, change, climate change, government, greenhouse, australia, coal, energy, world, minister
2 Economy & Industry (TS = 33.7 %))	6 Thermal coal exports	Ec	37.8	17.0	Debates about the coal industry and the importance of exports to the Australian economy.	coal, thermal, thermal coal, industry, coal industry, australian, australia, export, exports, power
	1 Coal industry and jobs	Ec	22.0	9.9	Debates regarding the coal industry and its role in the economy and for jobs.	coal, jobs, industry, queensland, coal industry, people, labor, power
	14 Coal ports for export	Ec	11.6	5.2	Debates about coal ports for export, including rail to ports, with a focus on Queensland and NSW.	coal, port, rail, terminal, chain, tonnes, hunter, coal chain, million tonnes, valley
	11 Coal infrastructure	Ec	3.1	1.4	Infrastructure supporting coal industry, with a focus on Queensland and NSW.	rail, government, infrastructure, queensland, transport, australia, industry, road, one, coal
	15 Australia & Japan trade	Ec	0.6	0.3	Implications of Japan's economy for trade with Australia.	government, australia, australian, recommendation, trade, japan, people, economic, industry, also
3 Industrial relations (TS = 9.1 %)	4 Long service leave	Ec	14.3	6.4	Debates regarding the provision of long service leave in the mining industry.	long service, service, coal, service leave, leave, long, industry, mining industry, coal mining, mining

(continued on next page)

Table 1 (*continued*)

Category	Topic label	TEF	Docs (%)	Topic share (%)	Topic description	Top terms based on c-TF-IDF scores
	3 Industrial relations legislation amendment bill	Ec	6.0	2.7	Focus on industrial relations issues, with an emphasis on the Industrial relations amendment bill.	Industrial, relations, industrial relations, commission, industry, union, government, bill, legislation, tribunal
4 Technology (TS = 23.0 %)	9 Coal-fired power stations	Ec	25.5	11.4	Debates about coal-fired electricity generation in Australia, including discussion of their retirement.	coal, fired, coal fired, power, fired power, gas, stations, power stations, generation, brown
	13 Carbon capture and storage	Ec	13.7	6.1	Debates about clean coal, and carbon capture and storage technologies.	coal, carbon, storage, energy, australia, power, capture, emissions, technology, industry
	5 Renewable energy and coal industry	Ec	12.1	5.4	Debates about renewable energy and its effect on the coal industry.	energy, renewable, renewable energy, government, power, coal, australia, industry, minister, going
5 Politics (TS = 5.6 %)	10 Senator Parer conflict of interest	SP	12.4	5.6	Debates about Minister for Resources, Senator Parer, amid revelations about his interests in coal mines.	minister, parer, senator parer, shares, bill, senator, prime, prime minister, interest, 1992
6 CSG (TS = 6.4 %)	0 Coal seam gas (CSG)	SP	14.4	6.4	Debates around coal seam gas (CSG) projects.	Seam, coal seam, gas, seam gas, coal, water, mining, committee, large, scientific

Note. A document can have more than one topic per category, as well as topics in multiple categories. TS = topic share, the percentage of all topics accounted for by the topic or category; Docs = the percentage of documents containing that topic; TEF = Triple Embeddedness Framework (Geels, 2014); SP = Socio-political category; Ec = Economic category.

Table 2
Topics extracted from news articles, with associated labels and top terms, grouped by category.

Category	Topic label	TEF	Docs (%)	Topic share (%)	Topic description	Top terms based on c-TF-IDF scores
1 Environment (TS = 9.2 %)	41 Climate change	SP	6.5	2.5	Debates and concerns about the effects of coal mining on climate change.	climate, emissions, climate change, australia, change, fossil, energy, coal, fuel, world
	4 Carbon pricing policies	SP	6.1	2.3	Debates concerning government carbon pricing policies.	carbon, emissions, scheme, climate, tax, change, australia, government, climate change, tax
	2 Coal infrastructure and Great Barrier Reef	SP	5.7	2.2	Plans and proposals for constructing infrastructure such as coal terminals and their potential impact on the reef.	reef, great barrier, barrier, barrier reef, port, queensland, great, terminal, abbot point, abbot
	6 Concerns over water catchments	SP	3.1	1.2	Impact of coal mining projects on natural environmental water in NSW.	water, mine, illawarra, mining, wollongong, coal, planning, catchment, longwall, sydney
	51 Water contamination	SP	1.6	0.6	Water contamination from coal mines.	epa, river, water, mine, yallourn, incident, dam, environment, clarence, coal
	13 Animal and plant species	SP	1.2	0.5	Concerns about the effects of mining on animal and plant species, including the Bimblebox nature refuge and other areas.	species, nature, mining, coal, health, mine, bimblebox, environment, refuge, hunter
2 Politics & Policy (TS = 6.0 %)	37 Mining Resource Rent Tax	Ec	3.7	1.4	Expected effects of the Mining Resource Rent Tax on mining companies	tax, mining tax, mrrt, mining, government, resource, rent tax, iron, rent, companies
	34 Corruption inquiry into exploration licence	SP	3.4	1.3	Corruption enquiry into Nucoal exploration licence awarded by former resources minister	licence, nucoal, doyles, doyles creek, icac, creek, corruption, maitland, macdonald, licences
	40 Mining royalties	Ec	2.9	1.1	Reports about mining royalties, such as reactions to increases	royalties, government, budget, state, royalty, queensland, tax, mining, industry, coal
	18 Corruption inquiries	SP	2.5	0.9	Corruption inquiries in which politicians and mining leases play a role.	obeid, icac, macdonald, corruption, inquiry, eddie, former, eddie obeid, family, obeid family
	3 Coal mining and elections	SP	1.8	0.7	Coal mining as a topic ahead of elections.	party, labor, election, greens, seat, government, vote, palmer, coalition, voters
	48 Nuclear power and uranium mining	SP	1.7	0.6	Concerns around nuclear power and uranium mining	nuclear, uranium, nuclear power, power, uranium mining, energy, australia, nuclear energy, climate, change
3 Protests (TS = 3.3 %)	26 Anti-coal mining protests	SP	8.0	3.0	Protests forming against various coal mines.	police, protest, protesters, metgasco, gas, people, arrested, coal, coal seam, seam
	56 Anti-coal mining protests in Newcastle	SP	0.7	0.3	Protests against coal mining in NSW, primarily occurring at the Newcastle port and rail line.	police, protesters, protest, Newcastle, coal, protests, climate, port, people, activists
4 Coal mining projects & communities (TS = 20.0 %)	17 Hunter valley horse industry	SP	10.5	4.0	Conflicts between horse and mining industries in the Hunter Valley	hunter, thoroughbred, drayton, planning, drayton south, mine, horse, bickham, mining, industry

Table 2 (*continued*)

Category	Topic label	TEF	Docs (%)	Topic share (%)	Topic description	Top terms based on c-TF-IDF scores
	27 Hunter Valley land use	SP	8.7	3.3	Land use conflicts in the Hunter Valley	hunter, land, mining, upper hunter, land use, government, strategic, coal, upper, valley
	42 Warkworth mine project	SP	6.0	2.3	Community responses to coal mine projects around Bulga	bulga, warkworth, rio, planning, tinto, rio tinto, thorley, thorley warkworth, mount Thorley
	36 Latrobe Valley	SP	5.8	2.2	Expansion plans and future of brown coal mining in the Latrobe Valley	latrobe, latrobe valley, power, hazelwood, valley, brown coal, victoria, station, brown, power station
	52 Caroona basin mine project	SP	4.8	1.8	Community concerns around Carooan basin mine project	caroona, bhp, caroona coal, bhp billiton, billiton, group, action group, coal action, mining, action
	21 Adani mine project	SP	4.6	1.7	Approval process, conditions and concerns around the Adani mine project.	adani, queensland, project, mine, carmichael, environmental, federal, government, jobs, approval
	22 Lithgow and Maules Creek mines	SP	3.0	1.1	Protests, concerns, approvals, and closures around Lithgow and Maules Creek mines	whitehaven, Lithgow, mine, maules creek, maules, whitehaven, creek, forest, coal, area
	24 Galilee basin coal projects	SP	2.5	0.9	Community responses and political issues around Galilee basin coal projects	alpha, 000, basin, queensland, mine, project, median, coal, galilee, mining
	50 Moolarben coal mine project	SP	1.7	0.6	Community responses and approval process around Moolarben coal mine	ulan, mudgee, moolarben, drip, mine, moolarben coal, council, goulburn river, coal, expansion
	14 Acland mine project	SP	1.4	0.5	Community responses and concerns about new mining approvals; high court case.	court, life, dad, mine, mum, loved, new hope, land, comment, Acland
	38 Margaret River coal projects	SP	1.4	0.5	Community resistance against coal mine proposals	margaret river, margaret, river, epa, ld, ld operations, region, proposal, mining, coal
	46 Traditional owners and heritage sites	SP	1.3	0.5	Effects of coal mining projects on traditional heritage sites	native title, title, native, traditional, aboriginal, tranditional owerns, adani, gomeroi, heritage, owners
	53 Cobbora mine project	SP	0.9	0.3	Plans to develop the Cobbora mine	water, cobbora, mine, dunedoo, groundwater, cobbora coal, bores, project, coal, coal mine
5 Economy & Industry (TS = 35.7 %)	16 Shares and stock market	Ec	19.9	7.6	Performance of share market including results of coal mining shares	cent, per cent, per, cents, shares, index, stocks, markets, us, rose
	19 Development of coal mining activities in NSW	Ec	8.9	3.4	Development and announcements about a range of projects in NSW, including state of approval process	mine, coal, million, tonnes, million tonnes, wambo, hunter, tonnes coal, company, open
	30 BHP & South32 spin-out	Ec	8.8	3.3	Various reports about BHP, including demerger of South32	bhp, billiton, ore, iron, iron ore, bhp billiton, production, per, cent, per cent
	32 Rio Tinto	Ec	7.3	2.8	Various reports about Rio Tinto	rio, riot into, tinto, production, per, cent, per cent, ore, quarter, year
	47 Development of coal mining activities in Queensland	Ec	6.9	2.6	Development and announcements about a range of projects in Queensland, including state of approval process	mine, coal, construction, tonnes, million, new, million tonnes, queensland, coking, company
	31 Trade balance	Ec	6.8	2.6	Effect of commodity prices, demand, and trade on the broader economy	cent, per cent, per, billion, budget, surplus, exports, growth, deficit, tax
	29 Commodity prices' impact on Australia's trade	Ec	6.3	2.4	Expectations and changes in mining commodity prices, including coal, and its impact on Australia's trade	iron, ore, iron ore, prices, price, per, cent, per cent, china, year
	33 Galilee basin coal project updates	Ec	5.1	1.9	Project updates around Galilee basin coal projects	coal, company, basin, queensland, galilee basin, galilee, project, alpha, mine, central
	12 Port and rail infrastructure	Ec	4.9	1.9	Existing or planned transport infrastructure supporting the coal industry	port, rail, coal, newcastle, infrastructure, track, hunter, trains, loader, port newcastle,
	39 Adani mine project finances	Ec	4.8	1.8	Financing issues for the Adani coal mine project	adani, project, carmichael, mine, queensland, banks, coal, finance, carmichael mine, indian
	23 Dalrymple coal port	Ec	3.3	1.3	Port and rail infrastructure with a focus on Queensland and the Dalrymple coal port	queensland, rail, coal, dalrymple bay, cyclone, terminal, water, mines, bay
	20 Xstrata & acquisition by Glencore	Ec	3.3	1.2	Various topics about Xstrata, and its acquisition by Glencore	xstrata, glencore, company, coal, mine, mines, operations, queensland, mining, jobs
	7 Thermal coal price and demand	Ec	2.8	1.1	International demand and prices, and factors influencing demand for thermal coal.	coal, prices, mining, demand, hunter, thermal, thermal coal, industry, australian, australia
	49 Exports to China	Ec	2.1	0.8	Factors affecting coal exports to China, including trade difficulties	china, trade, coal, australia, australian, india, chinese, energy, per, per cent
	45 Griffin coal mine	Ec	1.6	0.6	Placement of Griffin coal mine in Collie into administration; court cases	griffin, griffin coal, lanco, carna, collie, coal, company, workers, bluewaters, power
	55 Macarthur coal acquisition	Ec	1.4	0.5	Macarthur coal and its acquisition by Peabody	macarthur, macarthur coal, talbot, company, coal, offer, ken talbot, ken, Peabody, bid

Table 2 (*continued*)

Category	Topic label	TEF	Docs (%)	Topic share (%)	Topic description	Top terms based on c-TF-IDF scores
6 Industrial relations & Employment (TS = 6.6 %)	8 Industrial disputes and strikes	Ec	5.9	2.3	Reports about industrial disputes and strikes in the coal industry	workers, union, industrial, action, company, work, mine, strike, agreement, coal
	9 Mines and employment	Ec	5.4	2.1	Impact of coal mines on employment, both in terms of job creation and job losses due to mine site closures	jobs, coal, queensland, mining, mine, job, workers, industry, union, company
	15 Redundancies	Ec	3.3	1.2	Focus on redundancies from coal mines	workers, mine, company, employees, jobs, union, coal, arthur, centennial, redundancies
	44 Demand for skilled workers	Ec	1.5	0.6	Increasing demand for workers in coal regions and skill shortages	mining, industry, jobs, mackay, coal, people, queensland, sector, skills, regional
	35 FIFO	SP	1.3	0.5	Emphasis on community implications of FIFO (fly-in fly-out) employment method	town, fly, people, Moranbah, fifo, coal, industry, workers, caton
7 Health & Safety (TS = 5.2 %)	11 Dust and pollution	SP	4.2	1.6	Concerns over dust and pollution from mining affecting health and safety	dust, air, pollution, coal, air quality, hunter, health, Newcastle, quality, monitoring
	1 Mining accidents in Australia	SP	3.9	1.5	Reports about accidents at mine sites in Australia	mine, safety, underground, incident, workers, explosion, mining, coal, pike, miners
	10 Mining accidents in China	SP	2.9	1.1	Reports about accidents at mine sites with a focus on China	china, miners, mine, Xinhua, trapped, province, safety, accidents, killed, explosion
	54 Mining accidents globally	SP	1.7	0.6	Reports about mining accidents overseas	miners, explosion, mine, killed, accident, people, Erdogan, safety, blast, soma
	43 Black lung disease	SP	1.1	0.4	Pneumoconiosis (CWP) cases from workers inhaling coal dust	lung, black lung, black, disease, dust, pneumoconiosis, lung disease, workers, coal dust, cwp
8 CSG (TS = 14.0 %)	0 CSG and water concerns	SP	16.2	6.2	Coal seam gas projects and impact on water	gas, seam, coal seam, seam gas, water, csg, coal, industry, exploration, government
	5 Gloucester basin projects	SP	15.6	5.9	Community objections to extension of coal mining in the Gloucester basin and to the development of CSG wells.	gloucester, agl, gas, coal seam, seam, seam gas, community, coal, csg, water
	28 CSG and agriculture	SP	3.5	1.3	Conflicts between agriculture and CSG and mining	shenhua, plains, liverpool, liverpool plains, land, joyce, mine, farmers, water, watermark
	25 CSG trial site	SP	1.6	0.6	Underground coal gasification trial site and concerns over environmental damage	linc, ucg, gasification, coal gasification, linc energy, energy, site, queensland, Kingaroy, plant

Note. A document can have more than one topic per category, as well as topics in multiple categories. TS = topic share, the percentage of all topics accounted for by the topic or category; Docs = the percentage of documents containing that topic; TEF = Triple Embeddedness Framework (Geels, 2014); SP = Socio-political category; Ec = Economic category.

Table 3
Topics extracted from Twitter tweets, with associated labels and top terms, grouped by category.

Category	Topic label	TEF	Docs (%)	Topic share (%)	Topic description	Top terms based on c-TF-IDF scores
1 Environment (TS = 18.4 %)	4 Climate change	SP	12.9	7.1	Demands to stop coal mining amid climate change.	climate, climate change, change, new, coal, climatechange, new coal, auspol, coal mines, mines
	9 High-emissions industries	SP	5.4	3.0	Post about high-emissions industry, including coal and space.	mining industry, coal mining, industry, space, mining, industries, rockets, change, dioxide, carbon dioxide
	16 Methane emissions	SP	5.2	2.8	Tweets about methane emissions from coal mines, including comparisons to other industries.	methane, gas, coal, climate, emissions, industry, change, mining, new coal, mines
	3 Impact of coal mining on water catchments	SP	4.7	2.6	Posts about the impact of coal mining on water catchments, with a focus on the Sydney catchment.	water, coal, mine, catchment, groundwater, coal mine, creek, river, sydney, namoi
	5 Impact on Great Barrier Reef	SP	3.8	2.1	Tweets about the impact of coal mining on the Great Barrier Reef, many naming the Adani coal mine.	reef, barrier, barrier reef, great barrier, great, coal, mine, coal mine, tourism, coral
	21 Fauna impact	SP	1.6	0.9	Fauna effects of coal mining, with a focus on koala habitat.	koalas, leard, koala, habitat, forest, coal mine, mine, species, leard state, state forest
2 Politics & policies (TS = 24.6 %)	0 Political parties and coal mining	SP	22.3	12.2	Posts about the position of political parties towards coal mining, and politicians' support for coal mining	coal, lnp, industry, amp, mining, coal industry, labor, auspol, mines, coal mining
	14 Coal industry subsidies	SP	9.8	5.4	Discussions about taxpayers subsidising coal mines.	industry, coal industry, subsidies, coal, taxes, billion, coal mine, taxpayers, pay

Table 3 (*continued*)

Category	Topic label	TEF	Docs (%)	Topic share (%)	Topic description	Top terms based on c-TF-IDF scores
	12 Relationships between coal industry and political parties	SP	8.0	4.4	Post about political parties and their position to and relationships with the coal industry.	labor, coal, industry, coal industry, mines, libs, coal mines, mining, party, support
	18 Margaret Thatcher	SP	4.9	2.7	Tweets about Margaret Thatcher closing down the coal industry in the UK.	thatcher, coal, mines, coal mines, amp, margaret thatcher, mining, new coal, uk
3 Coal mining projects & communities (TS = 21.1 %)	1 Adani coal mine	SP	19.3	10.6	Tweets about a range of issue around the Adani coal mine, including different perspectives, protests, and subsidies.	adani, mine, adani coal, coal mine, coal, carmichael, stopadani, carmichael coal, india, adanis
	6 Mine approvals and court cases	SP	12.3	6.7	Covers a range of mine projects, particularly outcomes of approval processes and court cases.	mine, court, coal mine, nsw, coal, acland, expansion, nswpol, gloucester, extension
	13 Whitehaven Coal	SP	2.9	1.6	Tweets about Whitehaven Coal mines, raising a range of issues.	whitehaven, whitehaven coal, whc, vickery, maules, mine, creek, narrabri, dust
	19 Shenhua coal licence over Liverpool plains	SP	2.3	1.3	Post about the Shenhua Liverpool plains project.	shenhua, shenhua coal, mine, plains, liverpool plains, liverpool, coal, coal mine, shenhua mine, nswpol
	17 Indigenous concerns and coal mines	SP	1.7	0.9	Post about the impact of coal mines on Indigenous communities and heritage sites.	indigenous, aboriginal, coal, mining, mine, ask support, australian aboriginal, communities ask, support huge, aboriginal communities
4 Technology (TS = 4.2 %)	7 Renewable energy technologies	Ec	5.7	3.1	Includes positions both supportive of renewable energy technologies and critiquing their use in place of coal and fossil fuels.	solar, renewables, energy, coal, power, renewable, industry, jobs, renewable energy, cheaper
	20 Energy technologies	Ec	2.0	1.1	Tweets primarily supportive of coal and nuclear energy, and critical of renewable energy technologies.	renewables, industry, australia, energy, hele, wind, coal, solar, nuclear
5 Economy & Industry (TS = 6.3 %)	11 Coal industry and jobs	Ec	7.4	4.0	Discussions about the importance of the coal industry as an employer.	jobs, 000, coal, people, mining, industry, employs, coal mining, work, workers
	8 Coal exports to China	Ec	4.1	2.2	Discussions about coal exports to China.	china, australia, coal, mining, chinese, industry, export, australian, mines, auspol
6 Health & Safety (TS = 2.1 %)	10 Accidents and health hazards	SP	3.8	2.1	Post about accidents and health hazards due to coal mining, including black lung disease.	fire, health, lung, mine, coal mine, black lung, coal, black, hazelwood, mine fire
7 CSG (TS = 2.2 %)	15 Coal seam gas (CSG)	SP	4.0	2.2	Debates about coal seam gas (CSG) projects and land use conflicts.	nsw, csg, coal, gas, laws, mines, protect, coal mines, coal seam, seam
8 Coal mining (TS = 21.2 %)	2 Coal mining	–	38.6	21.2		Coal, mine, coal mine, mines, coal mines, coal mining, open, site, miner

Note. A document can have more than one topic per category, as well as topics in multiple categories. TS = topic share, the percentage of all topics accounted for by the topic or category; Docs = the percentage of documents containing that topic; TEF = Triple Embeddedness Framework (Geels, 2014); SP = Socio-political category; Ec = Economic category. During inspection of the topics and associated tweets, Topic 2 (Category 8) did not emerge to be substantial and meaningful, merely containing very brief tweets without a specific inferable meaning. We suspect that short responses to other tweets have been captured in this topic. Due to the lack of substance and meaningfulness, we have therefore omitted this topic from further reporting and analysis.

Data availability

The authors do not have permission to share data.

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