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Foraging for development: An analysis of the Swedish wild berry innovation system

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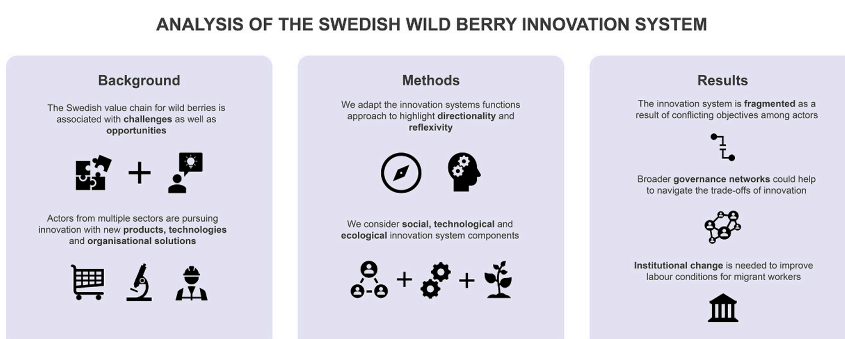
HIGHLIGHTS

- Attention to reflexivity and directionality is added to the agricultural innovation systems approach.
- The structure, functions and directionality of the Swedish wild berry innovation system are analysed.
- The innovation system is fragmented since incumbents are absent.
- There is a need for broader governance networks to navigate trade-offs.
- Successful innovation likely hinges on institutional change.

GRAPHICAL ABSTRACT



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ABSTRACT

CONTEXT: Driven by strategic objectives such as regional development, increased domestic value added, improved labour conditions and reduced environmental impacts, a range of actors are pursuing innovation related to the Swedish wild berry value chain.
OBJECTIVE: Our objective is to analyse the structure, functions and directionality of the Swedish wild berry innovation system and draw implications for ongoing efforts to develop the value chain.
METHODS: Our study is based on 18 semi-structured interviews, participant observations and a range of secondary sources. We use an analytical framework based on the agricultural innovation systems approach and pay specific attention to reflexivity, directionality and non-human materiality.
RESULTS AND CONCLUSION: The Swedish wild berry innovation system is fragmented as incumbent berry companies are absent from efforts to develop and reconfigure the value chain. The fragmentation is a result of the partly conflicting objectives among actors in the innovation system. There is a need for broader governance networks to navigate trade-offs and enable the commercialisation of new solutions. Successful innovation likely hinges on institutional change, particularly when it comes to efforts to improve labour conditions for migrant workers.
SIGNIFICANCE: Our study contributes empirically to research on non-timber forest product value chains and offers insights for actors pursuing innovation related to Swedish wild berries. We contribute to theoretical

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development in the agricultural innovation systems literature by incorporating attention reflexivity, directionality and non-human materiality.

1. Introduction

A 2023 survey comparing stakeholder perceptions of sustainability in the Swedish food system found broad support for increasing the domestic production of fruits and vegetables (Röös et al., 2023). While Sweden largely relies on imports in these food groups, Swedish forests produce up to a million tons of wild berries each year (Jordbruksverket, 2023; Nilsson et al., 2021). The Swedish value chain for wild berries is associated with both challenges and opportunities. On the one hand, labour conditions for migrant berry pickers are an ongoing source of concern, with recurring accounts of exploitation which have damaged the industry's reputation and resulted in calls for strengthened regulation (Axelsson and Hedberg, 2018; Carmo and Hedberg, 2019; Gollin et al., 2021; Kebebe et al., 2015; Wingborg, 2011). In addition, there are concerns about the effects of climate change on future berry growth and the environmental impacts of large-scale berry picking (Hedwall and Brunet, 2016). On the other hand, actors see a potential for regional development and increased domestic value added in the creation of berry companies based on new technologies and business models (Fairchain, 2023; Region Västerbotten, 2021; RISE, 2022). Food and drink products based on wild berries are also considered to be nutritious and have low environmental impacts (Aguilera and Toledo, 2022; Manninen and Peltola, 2013). Actors therefore see the wild berry industry as being able to contribute towards a more sustainable food system (Fairchain, 2023; RISE, 2022; Umeå University, 2023).

Against this background, multiple innovation efforts are underway which seek to develop or reconfigure the value chain for Swedish wild berries (Fairchain, 2023; Region Västerbotten, 2021; RISE, 2022; Umeå University, 2023). These efforts depart from slightly different views of and prioritization between opportunities and challenges, giving rise to trade-offs and contestation. We argue that this calls for research that investigates innovation in relation to the entire wild berry value chain, while acknowledging the existence of multiple development trajectories with different consequences for stakeholders. Previous research in the Swedish context has explored labour issues (Axelsson and Hedberg, 2018; Carmo and Hedberg, 2019; Eriksson and Tollefsen, 2018) and property rights (La Mela, 2014; Sténs and Sandström, 2014), but such system-level studies are currently lacking.

The aim of our paper is therefore to analyse the structure, functions and directionality of the Swedish wild berry innovation system and draw implications for ongoing efforts to develop the value chain. Following previous studies of agricultural innovation systems (AIS) (Kebebe et al., 2015; Minh, 2019; Turner et al., 2016), we adopt an analytical framework based on the functions approach developed within the technological innovation systems literature (Bergek et al., 2008a; Hekkert et al., 2007). Taking inspiration from recent contributions to the literature on transformative innovation policy and societal 'missions' (Bugge et al., 2022; Haddad et al., 2022; Hekkert et al., 2020; Klerkx and Begemann, 2020; Mazzucato, 2021; Wesseling and Meijerhof, 2023), our paper advances the functions approach to incorporate attention towards directionality and reflexivity. Here, we highlight the idea that innovation systems can propel developments in multiple directions, with different implications for actors' strategic objectives (Andersson et al., 2021; Stirling, 2011). Moreover, acknowledging calls to address the role of non-humans in AIS, we consider not only social and technological, but also ecological system components, which have an important influence in our empirical case and the agri-food sector more generally (Contesse et al., 2021; Hebinck et al., 2021; Pigford et al., 2018).

In addition to this conceptual development, which may benefit future research on innovation systems, particularly in the agri-food sector, our paper adds a novel empirical case to the literature on non-timber forest product (NTFP) value chains (Adam et al., 2013; Hamunen et al., 2019; Jensen, 2009; Mahonya et al., 2019). At a time when alternative directions for the food system are a pressing concern for science and policymaking (European Commission, 2020; Rockström et al., 2020; Willett et al., 2019), the distinctive characteristics of NTFPs, which require no additional land, water or fertilizer inputs, merits their investigation. Previous NTFP research has focused on subsistence gathering for households in low and middle income countries (Adam et al., 2013; Choudhary et al., 2014; Jensen, 2009; Mahonya et al., 2019), and despite taking place in a radically different socio-economic context, we find interesting thematic parallels between previous studies and our own, such as opportunities for rural development (Adam et al., 2013), issues of exploitation and inequity (Choudhary et al., 2014; Jensen, 2009) and uncertainty surrounding the ecological impacts of extraction (Shackleton et al., 2018; Ticktin, 2004).

In the following sections, we begin by introducing the Swedish wild berry value chain and the opportunities and challenges associated with its development (Section 2). We then describe how we build on the AIS approach in our paper's conceptual foundations (Section 3). In the following sections, we outline our analytical framework (Section 4), and present our methods and data (Section 5). Thereafter, our analysis proceeds in three stages: we begin by mapping the structural components of the Swedish wild berry innovation system; we then turn to the characteristics of six system functions; and lastly, we analyse the directionality of the innovation system (Section 6). The paper ends with a concluding discussion that outlines the conceptual and empirical implications of our analysis and addresses limitations in our study (Section 7).

2. Background

Wild berries grow across the length of Sweden and are particularly abundant in the northern forests where most commercial picking takes place. The most common and commercially significant species are the bilberry (*Vaccinium myrtillus*) and lingonberry (*Vaccinium vitis-idaea*), whose bushes cover nearly a fifth of Swedish forests and in some years produce over a million tons of berries (Nilsson et al., 2021). Many other wild berry species grow and are harvested in smaller quantities, such as the cloudberry which is the third most commercially significant (Casimir et al., 2018). Most forests where berries grow are privately managed and owned. However, no permission is required from landowners to pick NTFPs such as berries, mushrooms and wild flowers due to the right of public access (*Allemansrätten)*, a customary law which permits a range of outdoor activities on public and private land, applying equally to recreational and commercial picking (La Mela, 2014).

The wild berry harvest takes place in the late summer months, during which several thousand migrant workers fly in from Thailand to work as berry pickers (Migrationsverket, 2023). Berry pickers work intensively throughout the season, collecting around 25,000 tons of bilberries, lingonberries and cloudberries using simple handheld rakes (Fig. 1) (Andersson et al., 2024). Most workers are formally employed by staffing agencies based in Thailand (on behalf of a Swedish berry wholesaler), which arrange work visas and transportation in exchange for large upfront payments which are often covered with loans (Wingborg, 2011). The difficulty for regulatory oversight within these transnational employment arrangements, and the financial risks they place on workers, have been an ongoing source of concern surrounding the wild berry industry for the last two decades, amid repeated accounts of exploitation and in some cases human trafficking (Axelsson and Hedberg, 2018; Carmo and Hedberg, 2019; Eriksson and Tollefsen, 2018; La Mela, 2014; Nestby et al., 2011; Wikstr, 2021; Wingborg, 2011).

After picking, wild berries are collected by Swedish traders that supply domestic and international wholesalers. Swedish wholesalers also import around 10,000 tons of berries each year (Andersson et al., 2024). When berries arrive at wholesalers' facilities, they are first frozen and then cleaned and packaged for further distribution (Casimir et al., 2018). Out of the 29,000 tons of berries that are handled annually by Swedish wholesalers, 16,000 t are absorbed by domestic retailers and producers of berry-based food and drink products, which often mix domestically sourced wild berries with cultivated alternatives which have a lower price and more consistent supply (Andersson et al., 2024). The remaining 13,000 are exported to the European food industry as well as to the international bio-extraction industry, which serves a large consumer market for berry-based health supplements and cosmetics in East Asian countries (Antonella et al., 2018; Paassilta et al., 2009; NPR, 2015).

Medical uses for wild berries have been recorded since medieval times (Beck, 2005; Morazzoni and Malandrino, 1996), and recent years have seen growing scientific interest in their health-promoting properties (Cassidy, 2018; Ulbricht et al., 2009; Zafra-Stone et al., 2007). In particular, northern Swedish bilberries are in high demand in the bio-extraction industry due to their high levels of anthocyanins: coloured pigments in the berry skin which are valued for their claimed anti-oxidant properties (Åkerström, 2010). Although conclusive evidence is lacking, there are results which highlight various potential health benefits of Nordic wild berries. For example, a pre-clinical study recently demonstrated improved cognitive and metabolic function in mice (Huang et al., 2022).

As noted in the introduction, the Swedish wild berry value chain is characterised by both opportunities and challenges. To begin with, actors associate the large scale of natural berry growth with opportunities for upscaling and industrial development. Estimates suggest that around 2–5% of the total berry growth is harvested, while Sweden continues to import both wild and cultivated berries (Andersson et al., 2024; Casimir et al., 2018). At a national level, developing the value chain is therefore seen as a way to increase domestic food production and exports (RISE, 2022; Swedish Government, 2017), while regional opportunities for business development and job creation in Northern Sweden are perceived in connection with new technologies (Fairchain, 2023). The fact that wild berries have a low environmental impact, are nutritious, and increasingly associated with health benefits, also creates an expectation of market opportunities for value-added products and processes (Aguilera and Toledo, 2022; Blomhoff et al., 2023; Huang et al., 2022; Manninen and Peltola, 2013). At the same time, there are persistent problems surrounding the labour conditions for migrant berry pickers, uncertainties around the effects of climate change on future berry growth, and questions surrounding berries' status as a publicly accessible resource. These issues serve both as a motivation and obstacle for efforts to develop the value chain (Dagens Arena, 2022; Hedberg, 2021; Hedwall and Brunet, 2016; La Mela, 2014).

The value chain's socio-economic context is also distinguished by the 'multiple-use' profile of wild berries, which are associated with different kinds of value for different stakeholders (i.e. economic, ecological, recreational, cultural, nutritional or medicinal) (Byerly, 1971). Grivins (2016) contrasts the perceived economic insignificance of wild blueberry picking in Latvia with a significant economic and non-economic value for rural communities, and an associated potential for rural development, citing speculation that ownership patterns in NTFP value chains can support alternative economies (Grivins, 2016). Sténs and Sandström (2013), meanwhile, point towards the governance challenges which arise from conflicting notions of property in multiple-use situations involving NTFPs. Previous research has also explored how benefits are distributed when highly localized food resources like wild berries enter globalised market structures, and the effects this has in terms of social sustainability for local communities, migrant workers, and forest owners (Grivins and Tisenkopfs, 2018; Hamunen et al., 2019). The multiple-use profile of wild berries thus calls attention to how the rewards, and potential costs of developing commercial value chains are shared among stakeholders.

3. Conceptual foundation

An innovation system can be conceived as a constellation of structural components, such as actors, networks, institutions and infrastructure, which interact to enable or constrain innovation in a given context (Carlsson et al., 2002). The innovation systems approach was first developed to analyse the diverging economic performance of countries (Freeman, 1988; Lundvall, 1992; Nelson, 1993), but scholars have since developed frameworks that capture innovation systems related to

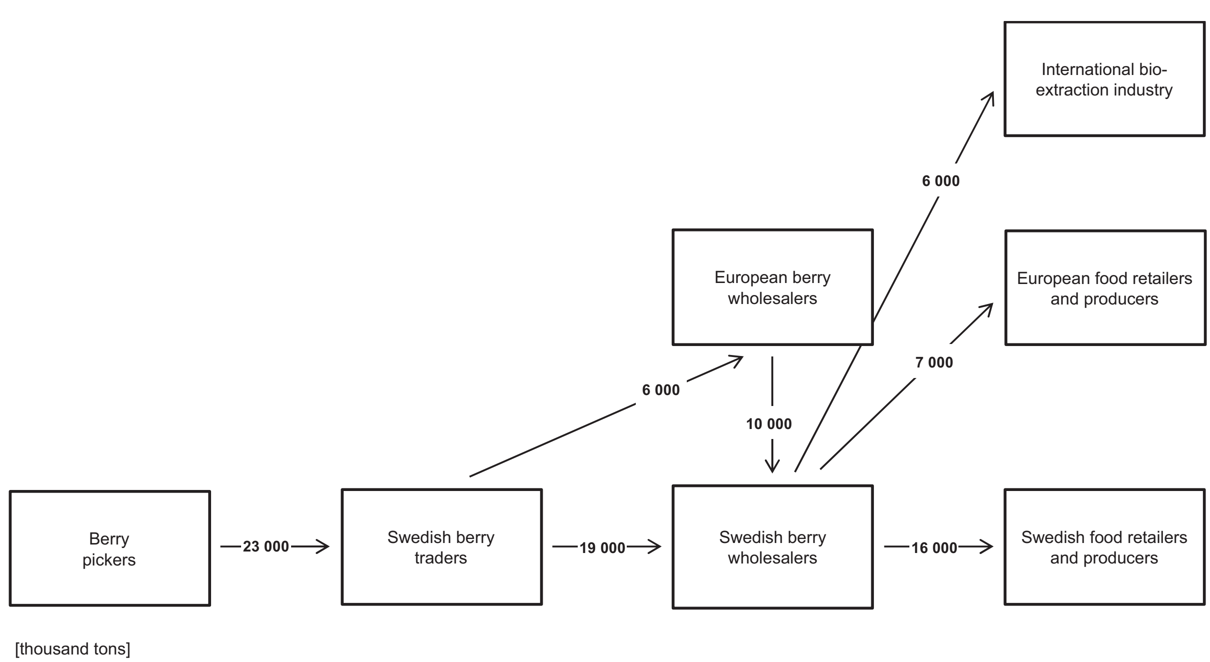

Fig. 1. Estimated flows in the Swedish wild berry value chain (Andersson et al., 2024).

geographic regions (Asheim et al., 2011; Cooke, 2008; Cooke, 2001), economic sectors (Malerba, 2005; Malerba, 2002), and technologies (Bergek et al., 2008a, 2008b; Hekkert et al., 2007; Markard and Truffer, 2008).

Looking beyond market forces, the innovation systems approach emphasises the importance of institutions and their evolution, as well as social, political and cultural factors, and how they differ between contexts.[1] With an inheritance in evolutionary and institutional economic theory, innovation is here conceptualised as a non-linear, non-optimal process, encompassing products, process and organisational forms (Meeusen, 2000). In our paper, we follow this approach and define innovation broadly in terms of the development and diffusion of novel products, technologies, organisational solutions, institutions and behaviours.

While early studies focused on the structural composition of innovation systems, analytical focus has shifted towards the functions an innovation system fulfils within its geographical, sectoral or technological context (Jacobsson and Bergek, 2011). This 'functional turn' originated in the technological innovation systems literature, where studies depart from frameworks based on system functions such as knowledge development, resource mobilization, legitimation and market formation (Bergek, 2019; Bergek et al., 2008a; Hekkert et al., 2007). Functions are conceived as sub-processes of the innovation process, resulting from actions and interactions between structural components in an innovation system, under the influence of contextual factors (Andersson et al., 2023; Bergek et al., 2008a). As shown by its widespread use in the sustainability transitions literature, the functions approach provides a useful analytical perspective for identifying barriers to the development and diffusion of new technologies and related industrial value chains (Bergek, 2019; Köhler et al., 2019; Savin and van den Bergh, 2021).

The functions approach has also been adopted in studies of national, regional and sectoral AIS (Kebebe et al., 2015; Klerkx et al., 2012; Minh, 2019; Turner et al., 2016; Valerio et al., 2022). Presenting a longitudinal analysis of the Ethiopian dairy AIS, Kebebe et al. (2015) connect structural weaknesses with inhibited functional performance, arguing that policy instruments must foster institutional as well as technological change. In another study, Turner et al. (2016) present a functional analysis of New Zealand's national AIS, identifying blocking mechanisms for co-innovation which are linked to underlying institutional logics. Minh (2019), meanwhile, combines a functional analysis with regional innovation systems concepts in a study of Vietnam's northern uplands AIS, arguing that this can support the development of effective policy instruments.

AIS studies often identify interventions which can enhance the functional performance of an innovation system (Lamprinopoulou et al., 2014; Menary et al., 2019; Minh, 2019). It can seem assumed, however, that a well-functioning innovation system will lead to desirable change, while less attention is given to the different directions change could take, and who stands to benefit (Kok and Klerkx, 2023). An indiscriminate attitude towards innovation has been raised as a shortcoming of innovation systems frameworks, a critique which aligns with the growing literature on transformative and mission-oriented innovation policy (Haddad et al., 2022; Janssen et al., 2021; Mazzucato, 2021; Parks, 2022; Schot and Steinmueller, 2018). As opposed to the supply-side lens of traditional innovation policy, this literature focuses on how innovation can be directed towards responding to societal demands and challenges, rather than technology diffusion and economic growth alone (Andersson et al., 2021; Kivimaa and Kern, 2016; Yap and Truffer, 2019). In line with this shift, scholars have proposed alternative innovation systems frameworks focusing on specific problems (Ghazinoory et al., 2020), or societal missions (Elzinga et al., 2023; Klerkx and Begemann, 2020; Hekkert et al., 2020).

Beyond merely facilitating innovation, innovation systems can thus be conceived as directing developments through the activities they prioritize and provide resources for (Bergek et al., 2023; Schot and Steinmueller, 2018; Weber and Rohracher, 2012). The 'acceptable development paths' through which innovation systems can contribute towards achieving societal objectives are often connected to the concept of directionality, the property of having or maintaining a direction (Andersson et al., 2021; Bergek et al., 2023; Könnölä et al., 2021; Weber and Rohracher, 2012, p.1043). In our paper, we conceive directionality as an orientation towards certain forms of development which emerges from the structural and functional characteristics of an innovation system. For example, if knowledge development is consolidated around a specific technology, and networks are in place to support the diffusion of such knowledge, some forms of development within the system become favoured. Efforts to steer directionality thus reflect prioritizations between different possible development pathways. However, just as innovation is conceived as non-linear and multi-dimensional, so too must directionality be seen as an emergent property which is beyond the direct control of actors in an innovation system.

Given that stakeholders are likely to differ in the development pathways they promote, directionality has been described as an 'inherently political' concept, calling attention to the influence of power dynamics within innovation processes (Bergek et al., 2023, p. 1113). A lack of attention towards power dynamics has been raised as a shortcoming of the AIS literature, with claims that this reflects a depoliticised and economic-utilitarian view on innovation (Pigford et al., 2018). In the wider innovation systems literature, calls have also been made for consideration of the ways in which power dynamics shape institutional arrangements and the allocation of resources (Cullen et al., 2014). A connection can thus be made between attending to directionality in AIS and considering how power dynamics affect the prioritization of activities (Akimowicz et al., 2022; Hall and Dijkman, 2019; Kok and Klerkx, 2023).

A concept closely related to the directionality of innovation systems is reflexive governance (de Boon et al., 2022; Manning et al., 2023). Building on the notion of reflexive modernisation as a stage of self-confrontation for modern societies, reflexive governance is conceived as being engaged with its own side effects and limitations (Beck et al., 1994; Voss et al., 2006). This means entering an ongoing confrontation with "the ambiguity of social goals" and "uncertainty about cause and effect relations and the feedback that occurs between steering activities" (Voss et al., 2006, p. 4; Susur and Karakaya, 2021). In practical terms, reflexive governance can be understood as a process of "anticipating, reflecting, and engaging before, during and after, and when acting upon decisions" (Manning et al., 2023, p. 115). In the context of agricultural innovation, this is seen as important to account for interactions between innovation efforts and broader societal processes, and address underlying normative and political dynamics (de Boon et al., 2022). Reflexive governance can thus be seen a means for actors within AIS to attempt to steer the directionality of innovation while attending to the power dynamics which shape such efforts. Structural factors such as organisational hierarchies, communication channels, and diversity among actors are likely to affect the capacity for reflexive governance within AIS.

Scholars of agricultural innovation and sustainability transitions have also argued that an emphasis on socio-technical dimensions has created a narrow conception of structural components within innovation systems (Ahlborg et al., 2019; Andersson et al., 2023; Pigford et al., 2018). Especially in the agricultural context, this is seen as neglecting the role of ecological factors within innovation processes (Andersen and Wicken, 2021; Contesse et al., 2021; Klerkx and Begemann, 2020; Kok and Klerkx, 2023; Pigford et al., 2018). Looking towards actor-network theory (ANT) and social-ecological systems thinking, Pigford et al. (2018) therefore argue for a need to explicitly consider the role of non-humans, such as ecological actants, when studying and attempting to navigate AIS. Contesse et al. (2021), meanwhile, combine ANT with the

[1] While this breadth of scope is seen generating important insights, a loss of analytical precision is seen as one of the associated costs (Meeusen, 2000)

multi-level perspective to analyse the role of an agricultural pest within an agri-food transition process. The influence of non-humans has also been connected to the directionality of AIS, insofar as ecological elements, physical infrastructure, and material artifacts can enable or constrain certain development pathways (Gumbert, 2019; Kok and Klerkx, 2023). On this basis, the influence of, and impact upon non-humans can be seen as important considerations for the reflexive governance of AIS.

4. Analytical framework

In the following, we depart from the conceptual foundation outlined in the previous section and describe the adaptations we make to the AIS approach to arrive at the analytical framework used in this paper.

Following the scheme of analysis proposed by Bergek et al. (2008a), originally developed for studies of technological innovation systems but later adopted by AIS scholars, our analysis begins with mapping the structural components of the Swedish wild berry innovation system. Proceeding from the argument that AIS frameworks pay insufficient attention to the role of non-humans, and acknowledging recent calls to broaden the structural scope of innovation system studies to include ecological components (Andersson et al., 2023), we expand our categories of structural components to include actors, networks, and institutions, technologies and non-human materiality.[2]

After mapping structural components, we go on to analyse the characteristics of six system functions. The list of functions used in this paper (Table 1) is based on the commonly used typologies introduced by Bergek et al. (2008b) and Hekkert et al. (2007). However, given our conception of innovation systems as not only facilitating innovation, but also having an important role in directing developments, we expand our list of functions. To capture the ways in which actors reflect upon and redirect innovation activities, and thus attempt to steer directionality, we add the function ‘reflexive governance’, taking inspiration from the mission-oriented innovation system framework proposed by Wesseling and Meijerhof (2023). The inclusion of a reflexive governance function is intended to shed light on how actors within AIS reason around and negotiate the prioritization of activities in relation to desirable development pathways. As discussed previously, we treat engagement with power dynamics and the non-human influence as important aspects of the reflexive governance process.

The last stage of our analysis looks at how the structural and functional characteristics of the wild berry innovation system shape its directionality. In contrast to Elzinga et al. (2023), we thus treat directionality as an emergent outcome of structural and functional characteristics, rather than in terms of a specific directionality function. This is another area where our framework differs from the original scheme of analysis proposed by Bergek et al. (2008a), which evaluates “how well the system is functioning” (p. 419). Instead, we focus on the different development pathways which are emerging, their potential outcomes, and who stands to benefit from them. This highlights strategic trade-offs between different pathways and their implications for power relations within the system, while less focus is given to assessments of functional strengths and weaknesses. This shift aligns with the “aspiration for purposive and directional innovation” in recent innovation policy literature (Diercks et al., 2019, p.890; Weber and Rohracher, 2012), and seeks to move beyond an indiscriminate and depoliticized view of innovation in AIS (Pigford et al., 2018).

[2] Although non-human materiality exerts an important influence on processes in innovation systems (i.e. by constituting a causal factor), we do not consider it a part of ‘actors’. This is not intended to marginalize its role, but rather a matter of distinguishing the intentionality of human beings that act in a context of social institutions from that of animals, plants and material objects.

Table 1
A typology of innovation system functions. Based on Bergek et al. (2008a) and Hekkert et al. (2007) with modifications inspired by Wesseling and Meijerhof (2023).

System function	Description
Knowledge development and diffusion	The development of new technical and social knowledge through research, development and demonstration as well as the diffusion of knowledge through scientific publications, popular reports and stakeholder interaction in industrial networks, innovation platforms and other fora.
Experimentation and commercialisation	The experimentation with new technological, organisational or institutional solutions, either within individual firms, multi-firm alliances or collaborative projects that may also include researchers and policymakers, as well as the commercialisation of products and processes based on successful experimentation.
Resource mobilization	The mobilization of skilled workers and human competence, financial capital, raw materials, land and other input factors, supportive technologies and infrastructure, and other key resources to the innovation system as well as their allocation to different technologies, organisations and geographical regions.
Market formation	The formation of niche markets for new products and processes, the subsequent growth and maturation of these markets as well as the simultaneous destabilization and decline of old markets for undesirable products and processes.
Legitimation	The creation of legitimacy for developing and diffusing new technological, organisational and institutional solutions as well as the withdrawal of legitimacy from undesirable solutions.
Reflexive governance	The critical reflection among actors in the innovation system about how enacted development pathways align with overarching objectives as well as the capacity of these actors to redirect innovation activities to strengthen this alignment.

5. Methods and data

Our analysis of the Swedish wild berry innovation system applies the analytical framework described in the previous section to a combination of primary and secondary data collected between 2021 and 2022. Primary data was gathered through 18 semi-structured interviews with stakeholders and experts (Appendix A). A purposive sampling strategy was adopted to capture different perspectives on wild berry innovation as well as to ensure that key actor groups were represented (Miles et al., 2013). Respondents were identified through a combination of earlier case research, network contacts, chain referrals and web searches. Our final sample consisted of six researchers with expertise in forest ecology, crop science, migration and nutrition (R1-R5); one regional policy strategist (P1); two representatives of industry organisations with expertise in landowner rights and food policy (I1-I2); four representatives from wild berry companies (W1-W4); a consultant to the berry industry (C1); and five representatives from food production and retailing companies (F1-F5). An interview guide designed around the six system functions in our analytical framework (Table 1) was used with the intention to build a broad first-hand account. Based on the respondent’s background and expertise, questions were also asked to inform our mapping of structural components. Interviews were supplemented with participant observations in a collaborative research project (RISE, 2022).

Secondary data was gathered from multiple sources. A Web of Science search for Swedish research articles related to wild berries was performed and the results were manually categorised according to topic (Scopus, 2021). The search string “((‘lingonberr*’ OR ‘bilberr*’ OR ‘cloudberr*’ OR ‘cowberr*’) OR (‘wild’ AND (‘*berries’ OR ‘*berry’))” was used 2021-04-21. Research projects were identified through the national research project database Swecris (Swedish Research Council, 2021). The search strings “blåbär”, “lingon”, “hjortron”, “skogsbär” and “vilda bär” were used 2021-11-08. A patent search was carried out using the database of the Swedish Intellectual Property Office (PRV) and the results were manually categorised based on titles and supporting documentation (Swedish Intellectual Property Office, 2022). The search string “(‘lingon OR blåbär OR hjortron’)” was used 2022-02-14. Relevant media articles in the print versions of three major Swedish newspapers were identified using the database Mediearkivet (Retriever, 2021). The search string “((blåbär* OR lingon*) AND (industri* OR bransch* OR export OR import))” was used 2021-06-03. Parliamentary motions and government reports were gathered through a search in the online database of the Swedish government (Swedish Parliament, 2021). The search string “((‘lingonberr*’ OR ‘bilberr*’ OR ‘cloudberr*’ OR ‘cowberr*’) OR (‘wild’ AND (‘*berries’ OR ‘*berry’))” was used 2021-04-21. In addition, company websites, industry reports and policy documents were consulted as supplementary data.

A qualitative approach modelled on thematic analysis was used to analyse the collected data (Braun and Clarke, 2023). The first stage involved manually coding interview transcripts and secondary data using a semi-formal approach, where our analytical framework provided categories to which statements and observations could be related (i.e. structural components and system functions) (Miles et al., 2013; Turner et al., 2016). Cross-checking of codes then took place within the research team to assess reliability (O’Connor and Joffe, 2020). The second stage involved identifying convergences and contradictions within each category, which was intended to mitigate bias and contribute to the validity of our findings (Creswell and Creswell, 2018). For example, respondents’ statements about knowledge development or legitimation were cross-checked with observations from our review of scientific articles and media articles. Although no strict boundaries were drawn, some forms of secondary data related more to a certain category than others, i.e. research articles to knowledge development. The final stage of our analysis involved interpretation in several iterations, following the steps in our analytical framework, to build our analysis of structural and functional characteristics and directionality.

6. Results and analysis

In this section, we present our analysis of the Swedish wild berry innovation system. We begin by describing structural characteristics, we go on to analyse system functions, and finally, we turn to directionality, highlighting the development pathways which are emerging, their potential outcomes, and the strategic trade-offs they imply.

6.1. Structural characteristics

Actors in the innovation system include individuals and companies throughout the wild berry value chain as well as a number of other stakeholders that influence innovation (Fig. 3). Traders and wholesalers have driven earlier technological innovations for cleaning and freezing berries (I12; Jonsson and Uddstål, 2002) and influenced regulatory changes relating to taxes and work permits (W2; W4). Food producers and retailers pursue research and development, participate in research and innovation (R&I) projects (F1; F2; F3; F5) and have driven change by attaching sustainability criteria to purchasing agreements (F1; F5). As the end users of berry products, consumers also exert an influence through their purchasing decisions, which may be influenced by media coverage (i.e. concerning health claims or labour issues) (F5). Despite being the largest work force in the value chain, migrant workers have a limited role in the innovation system, though some pickers modify their equipment as well as calling attention to labour issues (C1).

Beyond the value chain, industry organisations representing food producers, retailers and landowners, act as strategic intermediaries and have driven initiatives to establish responsible industry practices (I1; I2; Land Lantbruk, 2021). Researchers develop novel technological solutions for mapping, picking and processing berries, as well as investigating health effects (C1; R1; R2; R4; Berry Lab, 2023; Huang et al., 2022). Policymakers, government agencies and funding councils affect tax, migration and property regulations of particular relevance to the wild berry industry, support business development and fair labour conditions (especially in rural regions in Northern Sweden), and provide public resources to R&I projects (P1). Lastly, trade unions, media organisations and NGOs raise awareness about issues within the value chain and campaign on behalf of migrant workers (Dagens Arena, 2022; Dagens Nyheter, 2023; Kommunal, 2023; Wingborg, 2011).

Two main networks connect actors in the innovation system (Fig. 3). The first is an innovation network built around publicly funded R&I projects and regional development initiatives. One such project aims to establish value added berry processing industries in Sweden and develop novel food and drink products (RISE, 2022). Another project seeks to facilitate intermediate wild berry value chains at a regional scale, by supporting new small to medium size firms through ICT tools and business model innovation (Fairchain, 2023). A third project investigates alternative economies of entrepreneurship and work, and how they can promote social equity and rural development, with a focus on the role of migrant berry pickers (Umeå University, 2023). In addition, a region in Northern Sweden promotes a range of initiatives to stimulate increased commercial activity surrounding wild berries as part of its food strategy (Region Västerbotten, 2021).

The second type of network links berry traders and wholesalers. A wild berry industry association was previously formed to respond to challenges surrounding taxes and labour migration, and though now disbanded, this network continues to operate more informally to address shared challenges (W2; W4; Swedish Parliament, 2005). Between innovation and industry networks, a level of fragmentation can be observed in that traders and wholesalers are rarely represented in R&I projects. Upstream firms are generally located in rural areas, implying a spatial and possibly cultural distance to the often urban-centred actors that conduct research and promote innovation. Additionally, despite having an important stake in developments, there is a limited representation of migrant berry pickers and smaller food producing companies in both innovation and industry networks.

A key institution for wild berry innovation is the Swedish right of public access. By ensuring relatively open access to the vast forest landscapes in which berries are found, this law enables current business models and makes it possible for new actors to enter the industry (I1; Sténs and Sandström, 2014). While the law does not place an upper limit on picking volumes, other laws such as the Land Code do place certain limits on organised berry picking (Swedish Government, 1970). Another set of institutions that shape the business models of berry companies are regulations for the employment and taxation of migrant berry pickers, with changes to such regulations having played an instrumental role in shaping the current value chain (W4; Axelsson and Hedberg, 2018).[3]

Swedish and European labelling standards are also influential. For example, berries purchased from pickers without an employment contract cannot be certified by a major Swedish organic label, favouring the use of organised migrant labour (W4). In addition, EU regulations for health and nutrition claims affect the product and marketing strategies of food producers and retailers, and the direction of research and development activities (W4; EFSA, 2010). Lastly, informal institutions, such as the culture around recreational berry picking and related culinary traditions, shape political attitudes towards the right of public access and consumer attitudes towards wild berry products.

Moving to technology and infrastructure, the value chain depends on

[3] Although there has been some institutional development, such as a guaranteed minimum salary, additional financial checks on berry companies and the representation of berry pickers by a Swedish trade union, some see further reforms, such as an ‘employer pays principle’, as being necessary amid continued accounts of exploitation (Dagens Arena, 2022; International Labour Organization, 2018).

tools and machinery for picking, cleaning and freezing berries as well as methods for assessing and mapping berry growth. Advances in such technologies are therefore seen as being able to support alternative value chain configurations, and have proven to in the past (W2; R1; C1; Jonsson and Uddstål, 2002). The availability of domestic research infrastructure meanwhile shapes the types of experimentation which can take place with products and processing techniques. For example, facilities for processes such as freeze drying, air drying and bio-extraction are seen as limited in Sweden compared to neighbouring countries, constraining innovation in these areas (C1; F2).

Finally, wild berries, wild berry plants, and the ecosystems in which they grow both drive and constrain innovation efforts. The seasonality, fragility and perishability of berries have historically driven innovation in cleaning and freezing technology, but simultaneously constrain the use of berries in food production (Jonsson and Uddstål, 2002). This is aggravated by significant annual variations in the growth and spatial distribution of berries, with some years producing 2–3 times more than others due to local weather conditions (Fig. 2) (W1; Nilsson et al., 2021). This contributes to economic uncertainty in the value chain, particularly as climate change is likely to make berry growth even less predictable (R2; Hedwall et al., 2013). The remoteness and ruggedness of the ecosystems in which berries grow, the fact that bushes are close to the ground, and the constant presence of mosquitoes during the picking season, moreover, makes commercial berry picking physically strenuous work, unattractive to the Swedish labour force (I1; I2). Lastly, the biochemical properties of Nordic wild berries are linked with opportunities to develop new products with health benefits (Berry Lab, 2023; Kelly et al., 2018), as well as more efficient processing technologies that extract bio-active compounds along with juice and press cake that can be used in food products (RISE, 2022).

6.2. *Functional analysis*

6.2.1. *Knowledge development & diffusion*

Scientific knowledge development relating to wild berries in Sweden has mostly concerned the ecology, biology, toxicology and genetics of plants and ecosystems. However, knowledge about the environmental impacts of large-scale berry picking, and the effects of climate change on future berry yields, is considered lacking (R1; R2; I7; C1). Understanding of non-human factors which will shape the long-term viability of innovations may therefore be limited. There is also a lack of studies comparing the environmental sustainability of wild berries with cultivated alternatives, which could be influential for marketing wild berry products or leveraging environmentally-motivated subsidies.

A lack of clinical evidence for the health effects of wild berries are also raised (F5; R5). This has recently been taken up by a Swedish biotechnology company conducting research into the health effects of Nordic wild berries, with a view towards developing novel food products with proven health claims (Berry Lab, 2023; Huang et al., 2022). Successful clinical trials could see R&D funding and entrepreneurship around health-focused berry products increase, along with a potential growth in consumer demand and willingness to pay for wild berries. However, as with environmental aspects, comparative studies with cultivated berries appear relevant here.

Meanwhile, actors see Sweden as having a weak academic knowledge base around food processing technologies, including applications to wild berries (C1; F2). While technical knowledge can be accessed from the international research community, a lack of domestic research means there is no readily available competence pool for commercial actors to draw upon. Ongoing R&I projects indicate a strengthening of knowledge development in this area (Fairchain, 2023; RISE, 2022). However, navigating the informal networks and local circumstances that characterize the wild berry value chain is difficult without the tacit and localized knowledge which comes from years of experience (C1). A lack of established berry companies in innovation networks may thus be a barrier for commercialising new processing innovations (F2).

Although one research project is addressing this issue (Umeå University, 2023), another concern for knowledge development is the limited representation of migrant berry pickers in innovation and industry networks. The practical knowledge migrant workers have amassed through years of experience may, for example, be relevant to technological innovation with picking tools, while their perspective seems important within efforts to promote socially sustainable and equitable value chains (I2; C1). Seeking convergences between scientific research and the more situated knowledge of actors within the value chain may thus be a strategy for guiding knowledge development towards practical solutions.

6.2.2. *Experimentation and commercialisation*

Experimentation with new wild berry products, wild berry processing technologies, and other technological solutions, is mainly taking place in innovation networks (RISE, 2022; Fairchain, 2023). However, actors perceive challenges for subsequent commercialisation processes, with some established companies sceptical towards solutions developed in research projects, as they have not been exposed to the market, and researchers generally lack a commercial stake in their activities (R3; W2). Fragmentation between industry and innovation networks may again be seen as playing an undermining role here.

Among larger food producers and retailers, experimentation revolves around berry products where there is an established consumer demand,

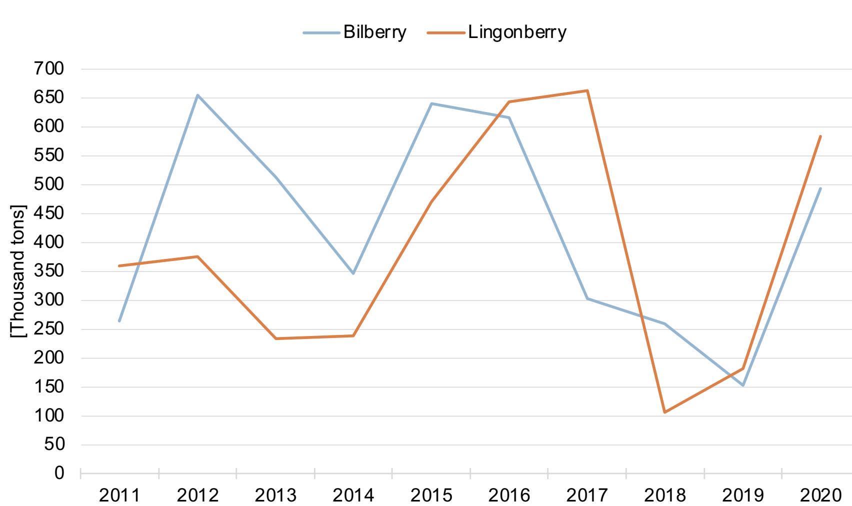

Fig. 2. Annual natural production of bilberry and lingonberry between 2011 and 2020 (Nilsson et al., 2021).

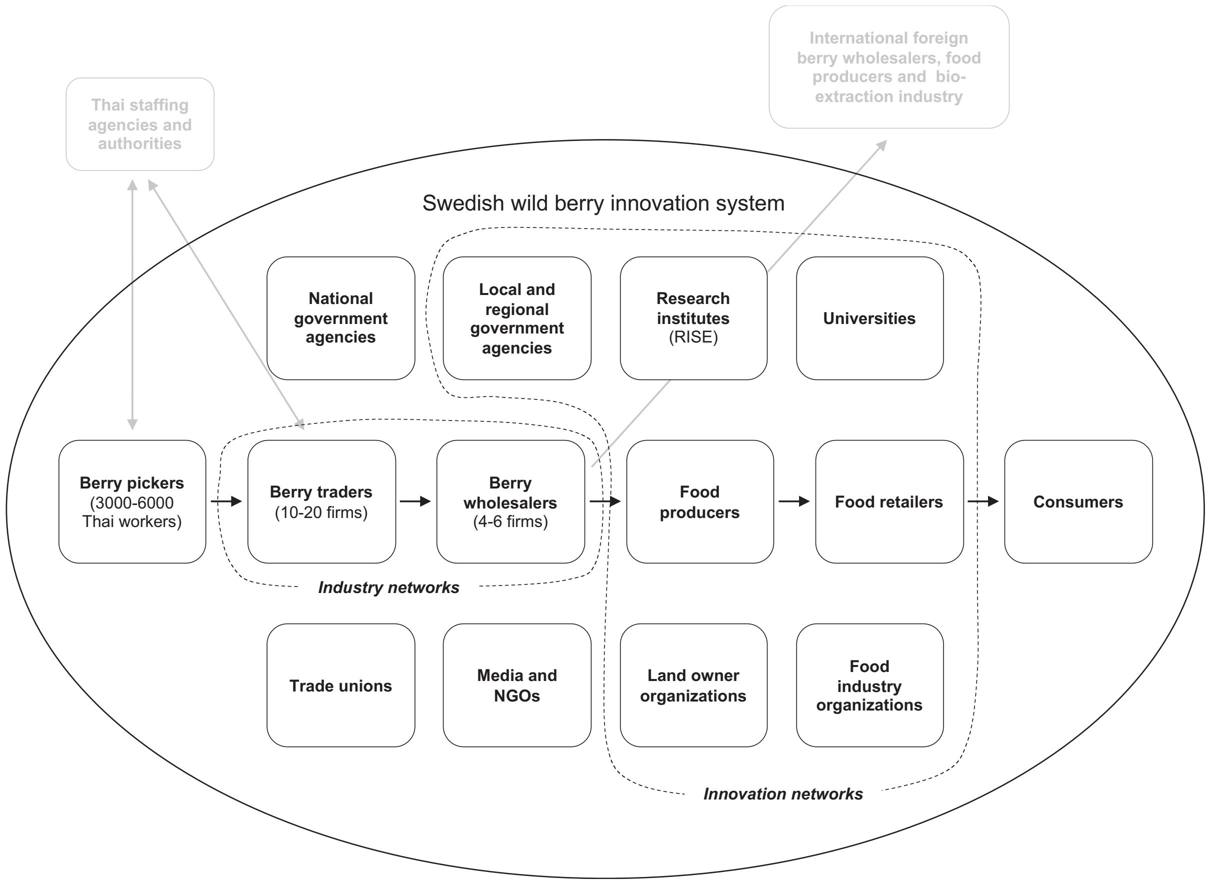

Fig. 3. A schematic illustration of actors and networks in the Swedish wild berry innovation system.

for example finding ways to produce berry jams with a lower sugar content (F1; F3). For these companies, a lack of clinical trials on the health effects of berries, and related institutions such as EU regulations for health and nutrition claims, weakens the case for developing novel, health-oriented food products (F5). The higher price of Swedish wild berries compared to imported and cultivated alternatives in another factor which lowers the incentive to experiment with new products, particularly in the absence of a scientific basis for marketing wild berries' potential sustainability benefits.

While early technological innovations in the wild berry value chain, such as freezing houses and cleaning technologies, were driven by berry wholesalers, these actors are now less inclined towards research and development activities (W1; W2; W3). This is due to the profitability of trading-focused business models and the investment risk associated with experimentation. Traders and wholesalers perceive an uncertain business environment in relation to ecological factors such as the variation of annual berry growth and the effects of climate change, along with changeable institutional and market conditions. This reduces their willingness to expand and makes it difficult to attract outside investors (W1; W2).

Start-ups and new entrants in the wild berry value chain are also relatively few, which is attributed to the strong position of established companies, a failure to diffuse research knowledge, and legitimacy concerns (C1; F2; F4). However, a handful of smaller, independent companies, based near the commercial picking centres in Northern Sweden have developed novel processes and berry products such as wines and premium juice concentrates (Idunn Wine, 2023; Saxhyttegubben, 2023). The fact that smaller companies outside of the core innovation system have successfully commercialised new products and processes suggests that their inclusion in innovation networks may valuable for efforts to commercialise solutions from research projects.

6.2.3. *Resource mobilization*

Regional, national and EU level public funding has been mobilised by previous and current wild berry R&I projects (Fairchain, 2023; RISE, 2022; Uddstål, 2014; Uddstål, 2011; Umeå University, 2023), and also to some extent by private actors. An EU grant allowed one wholesaling company to invest in new machinery, while regional development funds provide general business and innovation support to start-ups (C1; W1). However, investments that enable larger-scale experimentation and demonstration, together with networks that connect the relevant actors, are currently lacking.

A related human resource challenge is a perceived lack of entrepreneurs willing to enter the wild berry industry (R3). In response, one R&I project hopes that introducing modern technologies, such as berry mapping apps and picking robots, will attract a younger generation of entrepreneurs (Fairchain, 2023), while another project aims to support migrant pickers that want to engage with alternative economies of entrepreneurship and work (Umeå University, 2023). A lack of industry experts is an additional challenge for new entrants given the relative obscurity of the value chain (P1).

When it comes to material resources, actors see a shortage of facilities for processes such as air-drying, freeze-drying and bio-extraction, which corresponds with the perceived lack of domestic competence and expertise in these areas (F2). Although some technical equipment is available at research institutes, which also work actively to mobilize tools and machinery needed to experiment with wild berries (e.g. through the leasing of an industrial berry press) (C1), significant investment would be required to establish value added processing at an industrial scale, with some actors proposing private consortia as a solution (F2).

6.2.4. Market formation

Next to a relatively stable consumer market for traditional wild berry-based food and drink products in Sweden, demand for local, low-carbon and healthy food products has been increasing (Livsmedelsföretagen, 2020). Because traditional berry products tend to contain high volumes of added sugar, and often include imported berries, this suggests a receptive market for lower-sugar food and drink products made entirely from Swedish wild berries. This partly explains the mobilization of large food retailers to innovation networks and aligns with support among stakeholders and policymakers for increasing the domestic production of fruit and vegetables (F4; F5; Röös et al., 2023). Moreover, research pointing towards the health benefits of wild berries strengthens the existing market for health supplements as well as supporting new 'super berry' products in the growing market for functional foods (Antonella et al., 2018; Berry Lab, 2023; Kimura-Ovando, 2020).

At the same time, some food producers refrain from promoting Swedish wild berries and rather market more generic 'berry' products (F1). This is partly because using domestically sourced wild berries is not expected to increase sales, but also to maintain the flexibility of mixing in wild or cultivated berries from other countries, for example when the Swedish supply of wild berries is low or due to rising prices (F1; F4; Wiktorsson and Wilhelmsson, 2023). In a longer time perspective, market formation could also be weakened due to legitimacy concerns surrounding the recurring exploitation of migrant berry pickers (Carmo and Hedberg, 2019; Hedberg, 2021; Wingborg, 2011). Moreover, from an environmental perspective, a lack of knowledge development makes it uncertain whether commercially picked wild berries are more sustainable than cultivated alternatives (R2). This applies equally to the health effects of wild berry products, where successful clinical trials are needed to validate health claims (R5).

6.2.5. Legitimation

Legitimacy for wild berry innovation is strengthened by policies such as a national strategy to increase domestic food production (Swedish Government, 2017) and a regional strategy in northern Sweden which aims to increase local food production and exports (Region Västerbotten, 2021)(), as well as support among food system actors for increasing the domestic production of fruits and vegetables (Röös et al., 2023). However, concern about the labour conditions of migrant workers have damaged wild berry industry's reputation (Swedish Parliament, 2010), and although regulatory reforms are seen as having brought some improvement, which is reflected in the certification of several wholesalers by a major Swedish ecolabel (P1; I2; R5), such issues are far from resolved (Dagens Nyheter, 2023). Legitimacy concerns also surround the fact that a low-cost migrant workforce must be flown in to enable large-scale berry collection, which brings a substantial carbon footprint and reflects wider inequalities in the food system (F2).

Another longstanding legitimacy concern is the commercial exploitation of the right of public access. Since the early 20th century, parliamentary motions have sought to limit the access to private forests for organised commercial picking, or gain more control over the arrangement for landowners (Sténs and Sandström, 2014). While such efforts have made limited headway, they indicate weak legitimacy among some actor groups. The possibility of regulatory changes thus remains a source of uncertainty for the wild berry industry, especially since more efficient picking tools and increased harvests may raise new, potentially contentious questions concerning the legal boundaries for commercial access to wild berries (Elgenius and Wennerhag, 2018; Sténs and Sandström, 2014; I1; I2).

6.2.6. Reflexive governance

In R&I projects and related networks, deliberation upon the intended outcomes of innovation takes place through events such as scenario workshops and stakeholder dialogues. However, the different actors represented exhibit a range of strategic orientations (Fairchain, 2023; RISE, 2022; Röös et al., 2023; Umeå University, 2023). For example, while a clear path to market is seen as a high priority for commercial actors (F1; F5), this can appear secondary to societal and scientific concerns for researchers (R1; R4). Differing expertise may also shape the perception of opportunities and challenges within the value chain. For example, certain actors emphasise non-human aspects such as annual variations in berry growth (R1), while others stress concerns surrounding the right of public access (I1; P1). While they benefit from a breadth of competence, the reflexive governance of innovation networks thus becomes more diffuse and complex, as there is a need to accommodate different orientations and priorities when attempting to steer activities.

Food producers and retailers have multiple roles in directing the innovation system, as they not only participate within innovation networks, but also experiment with new products and influence the activities of trading and wholesaling companies. For these large companies, the lack of transparency associated with the wild berry industry, together with the repeated exploitation of migrant berry pickers, has led one actor to be hesitant to commit to sourcing wild berries (F1), while another prefers cultivated berries as they are traceable and picked under controlled conditions (F4). There are also instances where food producers and retailers have contributed to a reorientation of the industry by demanding that berry wholesalers adhere to social sustainability codes (W3).

Among private actors in industry networks, reflexive governance mainly relates to the role of the respective organization, but some coordination is facilitated through industry meetings and informal dialogues (Swedish Parliament, 2005; Wingborg, 2011). The desirability of innovation here tends to be evaluated in terms of business interests, which sometimes encompass concerns about social and ecological sustainability (W1; W2; W3). The closer proximity of trading and wholesaling companies to the natural variability of berry growth, both in physical and economic terms, seems to inform a more conservative outlook, and non-human materiality can here be seen as a factor influencing reflexive governance.

The pragmatism and localized knowledge which informs trading and wholesaling companies contrasts the longer term and broader perspective of R&I projects (R3). To the extent that these perspectives could be complementary when attempting to navigate innovation activities, fragmentation between innovation and industry networks can be seen as a structural characteristic which limits the reflexive governance of wild berry innovation. The limited network representation of migrant berry pickers and smaller food producing companies can also be seen as an undermining factor, insofar as the voices of actors with a considerable stake in developments become marginalised, reinforcing existing power imbalances within the value chain.

6.3. Directionality

The structural and functional characteristics of the Swedish wild berry innovation system give rise to multiple development pathways. Innovation networks have mobilised public funding with support from national and regional food strategies (Fairchain, 2023; Region Västerbotten, 2021; RISE, 2022; Swedish Government, 2017; Umeå University, 2023). Some initiatives aim to establish domestic processing industries based on advanced technologies and the introduction of new berry products (RISE, 2022), responding to market trends towards local, healthy and low-carbon products (Livsmedelsföretagen, 2020), and policy objectives such as regional development and increase domestic value added (Swedish Government, 2017). Others focus on the emergence of small firms based on new technologies and more localized value chains (Fairchain, 2023), or the empowerment of migrant workers through new business models (Umeå University, 2023), responding to legitimacy concerns over precarious situation of migrant berry pickers and the environmental impacts associated with food production and consumption (Hamunen et al., 2019; Hedberg, 2021).

The reconfiguration of the value chain these initiatives promote implies strategic trade-offs. The creation of new industries and products could lead to an increased demand for Swedish wild berries (RISE, 2022). However, if this happens without an improved regulatory framework for migrant berry pickers, problems with exploitation are likely to persist, which may make the continued reliance on this workforce untenable (i.e. if regulatory frameworks change due to persistent legitimacy concerns) (Dagens Arena, 2022; Dagens Nyheter, 2023). This could, however, stimulate innovation in areas such as automated berry picking technology, which has recently been developed for cultivated settings (Xiong et al., 2020), or business models that shift more profits to berry pickers. A growing annual berry harvest enabled by new technologies may also imply that fewer berries are available for recreational berry pickers and wildlife, or lead to exacerbated tensions with landowners (R2; W4). Moreover, new technologies that reduce the reliance on a low-cost migrant workers may imply a loss for berry pickers that are treated well and earn an income that is large in relation to their home countries (W2; W4; Fairchain, 2023).

Incumbent berry traders and wholesalers are largely absent within innovation networks (Fairchain, 2023; Region Västerbotten, 2021; RISE, 2022; Umeå University, 2023). This is partly a result of the uncertain business environment these actors are preoccupied navigating, faced with the natural variability of berry growth, the effects of climate change and the possibility of regulatory change (W1; W4; Hedwall et al., 2013; Nilsson et al., 2021; Sténs and Sandström, 2014). Incumbent companies have also co-evolved with the current value chain configuration and managed to gain strong market positions, while the knowledge, competence and resources that make their businesses profitable are often far from what is needed to develop and implement new social and technical solutions (W2; W4). When it comes to the creation of domestic processing industries, wholesalers are also hesitant since such investments may threaten their profitable business with processing industries in other countries (i.e. they would begin competing with their customers) (W2).

In contrast to innovation networks, incumbents are thus more invested in reconsolidating the current value chain through incremental innovation (W2; W4). This can involve individual activities or collaborative efforts in industry networks, which aim to increase berry volumes or improve the situation for migrant berry pickers (W1; W4). Such developments support the strategic objectives of traders and wholesalers, but could also benefit migrant berry pickers by securing continued work opportunities and improving labour conditions (on the margin). If incumbent companies maintain their existing business models, it may however be difficult mobilize the human and financial resources needed to establish new domestic processing industries. This may in turn hinder the emergence of new companies based on alternative technologies and business models. The incentive and capacity among berry companies to participate in efforts to reconfigure the value chain are accordingly limited. Combined with the difficulty of attracting entrepreneurs and investors (R3), a lack of domestic competence (C1; F2), and the importance of localized knowledge embedded in incumbent actors (F2), this implies an uncertain path towards commercialisation for new solutions that can contribute to developing and reconfiguring the wild berry value chain.

7. Concluding discussion

This paper has analysed the Swedish wild berry innovation system using an analytical framework based on the AIS functions approach. Our results highlight that the system is fragmented as a result of historical and concurrent dynamics, where actors are one of many sources of causal influence. A range of stakeholders to the wild berry industry work actively to reconfigure the existing value chain to promote regional development, increase domestic value added, improve labour conditions for migrant workers and reduce environmental impacts. Meanwhile, incumbent berry traders and wholesalers are absent from these efforts and rather focus on incremental innovation that departs from their business interests. This suggests that R&I projects and other efforts to develop the value chain should focus not only on research and experimentation, but also on involving actors that are willing to engage with the commercialisation of new technologies.

A possible approach to building better alignment between industry and innovation networks, and managing the trade-offs identified in this paper, is to establish an expanded governance network. This could bring together actors that currently operate independently or that are underrepresented in existing networks. If successfully facilitated, such a network can potentially enhance collective reflexivity through deliberation upon trade-offs. It may also provide opportunities to explore new collaborations and provide further support to small berry companies. In addition, it could be a way to address power imbalances in the value chain by attending to the voices and opinions of migrant berry pickers, whose influence upon innovation activities is currently marginal.

Technical and social solutions that seek to improve labour conditions for migrant berry pickers must also be economically viable. In the absence of technologies that reduce the need for manual labour, there may therefore be a need to complement the development of new products and processes with efforts to transform the institutions which govern the price of wild berries. One approach could be to develop national or regional certifications of origin, which would increase the awareness among consumers about the difference between Swedish and imported wild berries, and thereby possibly command a higher price. Similarly, the willingness to pay for wild berries could increase if product declarations had to more clearly distinguish them from cultivated alternatives. However, to the extent that market communications invoke health and sustainability arguments, there is a need for research that can substantiate such claims. If a consensus emerges that wild berries have social and environmental benefits not found in cultivated alternatives, it may be possible to make products more competitive, and thereby enable a higher compensation to berry pickers, through different types of subsidies.[4]

The study we have presented has practical implications for a range of stakeholders. On the policy side, our findings suggest that institutional reforms designed to improve working conditions for migrant berry pickers should adopt a holistic perspective. Policymakers should address not only the rules surrounding employment, migration and company oversight, but also wider economic and non-human factors which exacerbate precarious working conditions (i.e., price competition from imported berries and the volatility of natural berry growth), taking steps ensure that these risks are not absorbed by workers. When it comes to migrant workers our analysis suggests that while these actors currently have a limited influence upon innovation, their perspective could be valuable for efforts to promote a socially sustainable and equitable value chain, which reinforces our previous arguments for broader governance networks. For commercial actors, our analysis suggests that in light of knowledge gaps surrounding the nutritional and environmental benefits of wild berries, strengthened collaborations with research actors to establish the scientific basis for new product claims could have a strategic benefit.

Our paper adds an empirical case to the AIS literature while illustrating how attention to directionality, reflexivity and non-human materiality can be incorporated in the functions approach. Our analysis of directionality aligns with the assertion that AIS both enable and constrain innovation (Klerkx et al., 2012), and in line with previous research, we observe that the structural and functional characteristics of an innovation system can give rise to multiple development trajectories simultaneously (Andersson et al., 2021). Our findings show that negotiation between competing sets of interests is an important feature of innovation processes that depart from broader normative goals than economic growth and technology diffusion alone (Pigford et al., 2018).

[4] Notably, this is an accepted path towards radically reconfigured value chains in sectors such as energy and transportation.

In addition, our effort to account for non-human materiality has revealed the role of wild berry ecosystems in creating an uncertain business environment. Our findings thus support recent arguments for a socio-techno-ecological approach to innovation systems research (Andersson et al., 2023).

The study we have presented also adds an empirical case to the literature on NTFP value chains (Adam et al., 2013; Hamunen et al., 2019; Jensen, 2009; Mahonya et al., 2019). Our findings reinforce calls for more knowledge development about the ecological impacts of NTFP collection, which has been shown to have important implications for the long term economic and social sustainability of value chains (Ticktin, 2004). Despite contextual differences, we also see parallels between efforts to develop shorter and more localized wild berry value chains (Fairchain, 2023), and findings which show the importance of local capacity building for creating sustainable harvesting practices (Singh and Chatterjee, 2022). In addition, similarly to Sisak et al. (2016) study of non-market NTFPs in the Czech Republic, our study suggests the possibility of expanding governance networks to better manage commercial exploitation. Lastly, like Choudhary et al. (2014) study of Indian Bay Leaf value chains, our findings connect power asymmetries in the wild berry value chain (Carmo and Hedberg, 2019) with a need for further policy measures.

Further insight into the empirical case analysed in this paper could have been achieved by expanding the system boundary to capture actors in other sectors, who are not currently, but may become, highly influential as innovation efforts unfold (i.e., robotics and medicine). Our system boundary was also limited to Sweden despite dealing with a value chain that includes complex international networks of trade and migration. In addition, we acknowledge that our research process reproduced one of our own critiques by failing to include interviews with migrant berry pickers, although we were able to build on the work of previous researchers to fill this gap (Axelsson and Hedberg, 2018; Carmo and Hedberg, 2019; Hedberg, 2021). This leaves ample room for future research to build upon and enhance our findings by adopting broader system boundaries and improving the actor representation.

CRediT authorship contribution statement

Paul Plummer: Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Johnn Andersson:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Thomas Taro Lennerfors:** Writing – review & editing, Supervision, Investigation, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The authors do not have permission to share data.

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Appendix A

Table A
List of interviews and interviewees.

Category	Code	Perspective	Type	Date	Duration
Research	R1	Forest ecology researcher	Zoom	28–01-22	60 Minutes
Research	R2	Forest ecology researcher	Zoom	09–02-22	60 Minutes
Research	R3	Crop science researcher	Zoom	13–12-21	60 Minutes
Research	R4	Migration researcher	Zoom	16–12-21	60 Minutes
Research	R5	Nutrition researcher	Zoom	09–11-21	60 Minutes
Research	C1	Berry industry consultant	Zoom	16–11-21	90 Minutes
Public sector	P1	Regional policy strategist	Zoom	18–05-21	60 Minutes
Industry association	I1	Landowner rights expert	Zoom	11–11-21	60 Minutes
Industry association	I2	Food industry policy expert	Zoom	30–03-21	60 Minutes
Wild berry industry	W1	Berry trader purchaser	Zoom	18–02-21	60 Minutes
Wild berry industry	W2	Berry trader/ CEO	Zoom	28–05-21	60 Minutes
Wild berry industry	W3	Berry trader/ purchaser	In Person	23–11-21	120 Minutes
Wild berry industry	W4	Berry trader/ business manager	Phone	10–02-22	60 Minutes
Food industry	F1	Food producer/ product development manager	Zoom	16–02-22	60 Minutes
Food industry	F2	Food producer/ innovation manager	Zoom	22–10-21	60 Minutes
Food industry	F3	Retailer/ range selector	Zoom	04–02-22	60 Minutes
Food industry	F4	Retailer/ purchaser	Zoom	18–02-21	60 Minutes
Food industry	F5	Retailer/ purchaser	Zoom	06–05-21	60 Minutes

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