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Modeling drivers and barriers to circular trade between the United Kingdom and European Union in the agri-food sector: a systems thinking approach

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The circular economy has gained increased attention as an actionable framework for creating more sustainable economic systems that reduce waste and pollution. Often excluded from discussions of circular economy is international trade and circular economy applications in the agri-food sector, despite their significant climactic impact and evidence for increased circularity potential. The trade relationship between the United Kingdom (UK) and European Union (EU) offers a unique case study for investigating drivers and barriers to greater circularity in international agri-foods trade. Though both parties have voiced commitments to fostering circularity into their respective economic systems, few concrete measures to promote circular trade have been considered between the UK and EU. In this paper, a literature review was conducted to establish a definition of circular trade as it relates to agri-food sector activity and propose ways to increase circularity in this case study. A combined literature review and systems thinking approach was used to model drivers and barriers to circular trade in the case study context via causal loop diagrams. This study found that policy-based interventions at multiple levels, from international to nation-level regulations and policy, should be leveraged to facilitate circularity of trade by increasing ease of performing circular trade activities. This includes adapting intellectual property rights legislation to better facilitate reuse and repair activities and harmonizing key definitions and procedures to increase reciprocity of goods and services to better enable reuse and repair activities inherent to circular activities. Further research should aim to refine best practices in circular trade within agri-foods as there is currently a gap in quantitative data to inform optimal circular value chain activities.

KEYWORDS

circular economy, agri-foods, systems thinking, causal loop diagram, international trade

1 Introduction

Circular economy (CE) principles have gained increased attention for their potential to mitigate the waste, resource extraction and environmental degradation inherent to the current "linear" paradigm of economic activity (Barrie and Schröder, 2021). There is a gap in research, however, on how CE approaches could apply to international trade despite its critical importance to the present highly globalized economic system. Key global stakeholders such as the Organisation for Economic Co-Operation and Development (OECD) and the World Trade Organisation (WTO) have voiced commitments to making trade more circular to combat climate change and diversify economic activity while meeting the needs of a growing

global population (Steinfatt, 2020). In 2021, the United Nations Economic Commission for Europe hosted a roundtable titled Fostering Circularity in Food Trade, which brought together key government leaders, researchers, and businessowners and highlighted potential avenues for circularity in the European agri-foods sector. This signals that a further area of research that is relatively unexplored includes introducing CE principles to trade in the agri-food sector. The agri-food sector is a significant source of global emissions and contributes to decreased biodiversity globally (UNECE, 2021). The United Nations Food and Agriculture Organization (UN FAO) estimates that this sector accounts for 31% of global greenhouse gas (GHG) emissions. Agri-food systems are also highly dependent on trade, where one-third of agricultural and food exports are traded in a global value chain, or cross international borders at least twice prior to consumption (UN News, 2021).

The trade relationship between the United Kingdom (UK) and European Union (EU) offers a unique case study for investigating how a transition to a more circular trade (CT) system could occur in the agri-foods sector. The UK's exit from the EU in 2020 allowed for a drastic re-evaluation of the two entities' trade relations, which could pave the way for integrating more circularity in these exchanges. The EU and UK are also significant trade partners in agrifoods. The UK is the top single country importer of EU agri-food goods, with 20% of EU agri-food exports going to the UK. The UK imports 46% of the food it consumes, with 60% of these imports coming from the EU, making this trade relationship critical to the UK's overall food security and diversity of food offerings, especially in fresh produce, the majority of which is imported (DEFRA, 2021). Both the UK and EU have begun to undertake some circularity-promoting measures, but these remain limited, especially in agri-foods and trade. Implementing circular trade practices could reduce emissions in the EU and UK's agri-food sector and reduce waste throughout agri-food value chains, hence interest in the UK, EU and international economic actors such as the UNECE and WTO in further exploring circular trade interventions (Sverko Grdic et al., 2020; UNECE, 2021).

1.1 Defining circularity in agri-food trade

Though there is no standardized definition of CE, The Ellen MacArthur Foundation, a leading research entity on circular economy, defines circular economy as a "systems solution framework" whose core objectives are to "eliminate waste and pollution, circulate products and materials at their highest value, and regenerate nature." The Ellen MacArthur Foundation (2023) and Barrie et al. (2022a) also stated that circular product design and changing consumption patterns are central to achieving these aims, as is the promotion of human and environmental wellbeing alongside circular economic activity. "Circular trade" encompasses any international trade transaction that contributes to circular economic activity at a local, national, or global levels. It is key to note that nation-level CE activity will form the basis for international CT transactions (Barrie et al., 2022a, 2022b).

Other researchers also reflect the Ellen MacArthur Foundation's definition, including Barrie et al., which categorizes circular economic activity into four components: "[1.] slowing the rate of flow of materials through the economy; [2.] narrowing material flows by doing more with less" and "[3.] looping materials back into the economy at the end of their life cycle"; and "[4.] regenerating natural systems (Barrie et al., 2022a). These categories, and the concepts of "slowing," "narrowing," "looping" and "regenerating," provide an action-oriented framework for a transition from the current "linear" economic paradigm to a more circular one. Any implementation of circular economic activity will require a transitionary phase given that these activities are not currently widely implemented, including in the target areas of this research, the UK and EU, which will be discussed in further detail in subsequent sections (Barrie et al., 2022a; Ghisellini et al., 2016).

Circular trade can also encompass international exchange of "circular economy-enabling goods, services and intellectual property (IP)" (Barrie et al., 2022a; Yamahuchi, 2022; TESS, 2024). "Circular economy-enabling goods" are goods that are designed and manufactured for circularity within their lifespans. They may also promote circular economic activity in their function, such as machinery used in recycling processes. Trade in second-hand goods and remanufactured goods are also key trade flows as they extend the overall lifespan of products. Secondary raw materials, or materials that are by-products or end-of-life products that can be used in the production of other products in lieu of extracting virgin material, are also a key component of circular trade (Barrie et al., 2022a; Despoudi et al., 2021; Vegter et al., 2020). For instance, in the production of soya bean oil, fiber from the soya plant remains that can be converted into a cake that can be used for animal feed—when traded internationally from the origin country, this activity would constitute circular trade (Barrie et al., 2022a).

Services are another key element of circular trade activity since they are essential to supporting all circular activity along supply chains. Workers skilled in facilitating a circular transition will also be critical to making circular trade a reality. Intellectual property rights (IPR) and IP trade also constitute a key element of circular trade since exchange of information regarding manufacturing and production of goods is needed to repair machinery, for instance, that was manufactured in another country to extend its lifespan within the importing country (Tamminen et al., 2020).

The concept of a "value chain" is also useful in discussions of circular economy. A value chain differs from a supply chain in its scope. While a supply chain encompasses the logistics of processing raw materials into finished products and their distribution to consumers ("primary activities"), a value chain extends to include what happens to products after they are used or have been "consumed." It also includes infrastructure, services, technology, and procurement practices that were involved in producing those products, which are considered "support activities"(Eisenreich et al., 2022). This is especially relevant to circular economy since what happens with products after consumption is essential to circular processes.

Figure 1 summarizes aspects of circular economy value chains and provides examples of types of activities that constitute circularity. It is adapted from Barrie et al. (2022a) and its overview of key circular economy activities, support activities, and how they interplay to form components of circular trade value chains (Barrie et al., 2022a).

1.2 Research aims and overview

This paper provides an exploratory analysis of drivers and barriers to CT between the UK and EU in the agri-food sector using systems

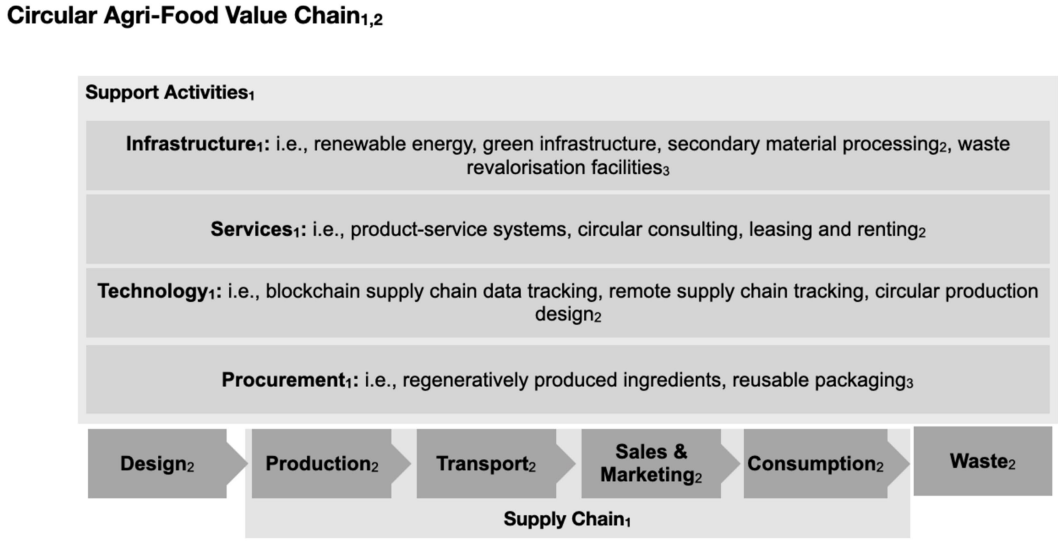

FIGURE 1
Diagram illustrating circular value chain components in agri-foods. Supply chain activity for food production generates waste, which in a circular system should be valorised or reused whenever possible. This occurs via "support activities" listed. "Supply chain" and "support activities" definitions adapted from Porter's definition of value chains (Porter, 1985) and Eisenreich et al.'s (2022) analysis of value chains in circular economy. Examples of circular support activities adapted from Barrie et al., as well as supply chain activities indicated in dark gray (2022) (*Created in Apple Keynote).*

thinking. Systems thinking allows for understanding how variables and different structures within complex systems interact. It can also help identify leverage points where changes to the system can be made to affect overall system outcomes (Sternman, 2002; Meadows, 2008). In Section 2, this paper aims to build upon the definition of circular trade in agri-foods established in the introduction by identifying factors within the UK-EU agrifood trade relationship relevant to circularity of trade in this sector, determined via literature review. Section 3 provides an overview of systems thinking methodology used to create the causal loop diagrams (CLDs) described in Section 4. CLDs are a valuable tool for visualizing complex system dynamics and identifying points of leverage within complex systems for affecting change (Crabolu et al., 2023; Meadows, 2008). Section 4 describes how elements affecting UK-EU trade in agri-foods affect overall system circularity. Section 4 also outlines proposed interventions based on the review of literature and CLD modeling. Section 5 discusses key findings on how to increase circularity in the EU-UK agri-food trade system and proposes areas of future research.

2 Conceptual framework

2.1 Defining framework elements

A literature review was conducted to establish a definition of circular trade in agri-foods and the types of activities that comprise this activity, which are summarized in Figure 1. A review of grey (i.e., government reports, policy documents) and academic literature was then conducted to determine system equivalencies in the UK-EU agrifood trade system. This represented the "scope" of the case study system that would be modeled by the CLDs in Section 4.

Factors relevant to circular trade were subdivided into policy, market dynamics, and research and design factors based on strong emphasis of these factors in the review of literature (Barrie and Schröder, 2021; Kuch, 2022). These factors, drivers and barriers and case study examples are summarized in Table 1. Analysis conducted in Europe and the UK was prioritized for applicability to the case study context. UK and EU-specific equivalent factors were then determined via further search of academic and grey literature, such as government reports and policy briefs. Where appropriate, factors that functionally overlapped with CE or CT activity but did not use circularity language were used as a proxy for CT activity, such as green trade or sustainability-related initiatives. Table 1 highlights key CFEs, drivers, barriers, and example activities relevant to the case study.

2.1.1 Policy factors

Policy was widely cited as highly influential to circularity of economic activities and was therefore included as a key factor to be considered in CLD construction. Policy also has the potential to promote key drivers of circularity identified in the literature, such as harmonization of regulations and standards, monitoring frameworks for circularity, and laws governing acceptable waste management practices (Barrie and Schröder, 2021; Sverko Grdic et al., 2020; Kirchherr et al., 2018). The UN Economic Commission for Europe (UNECE), which has also reiterated the need for greater circularity in agrifood sector trade, states that policy interacts with several areas relevant to circularity, listing "investment, innovation, digitalization and procurement" as priority actions (UNECE, 2021). Policy relevant to the case study includes multi-lateral global trade policy, namely that laid out by the WTO and Basel Convention, bilateral UK-EU trade policy, and respective UK and EU policies affecting the agri-food sector (Barrie et al., 2022a). WTO harmonization of CE standards and definitions was also cited as a driver for facilitating CT activity (Barrie and Schröder, 2021). Sustainability-focused working groups like the Trade and Environmental Sustainability Structured Discussions (TESSD) and the Committee on Trade and

TABLE 1 Drivers and barriers to circular trade (CT).

Analytical category	Factor influencing CT	Driver	Barrier	Incentive mechanisms
Policy and regulation	WTO Policy	Trade standard harmonization	Trade standard heterogeneity	Policy requirements and recommendations
	UK trade/agrifood policy	Circular supply chain standards	"Linear paradigm"	Benchmarks for waste and environmental health
	EU trade/agrifood policy	Standardized definitions of circularity	Definitional heterogeneity	Emissions goals
	UK-EU trade/agrifood policy	Multi-stakeholder discussion forums	Lack of communication around circularity	PTAs for circular goods
	IPR accessibility	Frameworks for assessing circularity	Lack of CE/T information gathering	
		Circularity protocol standardization	Lack of CE/T protocol and standardization	
		Free trade in circular goods	Non-tariff barriers	
Market dynamics	Comparative advantages	Evidence for circular best practices	Uncertainty around best practices	Subsidies/funding for circular business practices
	Supply and demand	Demand for circular goods	Lack of awareness around circular goods	Consumer and business education around circular goods/food waste
	Costs of CT twice activities			
	Availability of CE-skilled labor force			
Research and design	Research goals	Circularity focused R&D	Lack of prioritization for CE/T R&D	Government research/funding schemes
	Research funding	Funding for circular R&D	Cost of research	Further education around CE/T at universities
	Design goals	Circular design goals	CE/T research complexity	
	Existing circular infrastructure		High need for stakeholder coordination	

Environment (CTE) can further inform WTO policies to enhance circularity (Steinfatt, 2020).

2.1.1.1 World Trade Organisation

The role of the WTO is to regulate and facilitate international trade in goods, services, and intellectual property rights, to which the UK and EU member states are subject (Oatley, 2017). In a literature review investigating the ways in which international trade could facilitate a global circular economy transition, Barrie and Schröder identified "leveraging the role of the WTO" and "harmonizing circular economy standards and definitions" as key recommendations for increasing circularity in trade. The current lack, therefore, of harmonization of standards and definitions hinders circular trade. In 2020 the WTO announced its commitment to promoting circular trade via a working paper outlining possible avenues for greater circularity within WTO policy (Steinfatt, 2020). Such action on the part of the WTO could promote circular trade between the UK and EU (Barrie and Schröder, 2021).

Another WTO activity that influences circularity in trade and could act as a driver are its forums for international cooperation on sustainability issues. Working groups like the Trade and Environmental Sustainability Structured Discussions (TESSD) and the Committee on Trade and Environment (CTE) can further inform WTO policies to enhance circularity if intentional efforts to do so are undertaken. Furthermore, WTO policy is a key aspect of overall trade policies since governments are required to report any policies that may affect other states to the WTO in the form of notifications, and all trade agreements between the two parties must comply with WTO rules, which could be designed to foster circularity (Steinfatt, 2020).

2.1.1.2 EU policies

EU policies relevant to the case study are namely the EU Circular Economy Action Plan (CEAP) under the European Green Deal (European Commission, 2023a). The plan does not currently have extensive legislation addressing circularity in agriculture (European Commission, 2023b). The EU has existing monitoring efforts in all EU states for "circularity indicators" such as recycling rates, raw materials consumption, and product environmental footprints, key for quantifying existing CE practices and identifying areas of improvement (Sverko Grdic et al., 2020; Vercalsteren et al., 2018). The European Commission also passed a package of measures in 2023 requiring more sustainable soil management that include harmonized definitions of soil health, a monitoring framework, and protocols for sustainable soil management and remediation, which also could overlap with the restorative agricultural practices essential to circularity in agri-foods (European Commission, 2023b). Such policy

measures can be considered drivers for CT, even if the language of circularity is not explicitly included in these policies.

2.1.1.3 UK policies

After leaving the EU and CAP, the UK now oversees and funds its own agricultural production. Domestic agricultural affairs are overseen on a devolved basis, meaning the governments of the respective UK nations (England, Scotland, Wales, and Northern Ireland) manage these activities. On a UK-wide basis, the central government adopted the Circular Economy Package (CEP) in 2020 (DEFRA, 2020). Such legislation, which specifically promotes circular economy actions, can also be considered a driver to circular trade.

International trade is managed by the central UK government, including food trade (UK Board of Trade, 2021). Food production and trade is managed by the Department for Environment, Food, and Rural Affairs (DEFRA), though legislation related to the UK's food system is spread over other departments. The Department for Science, Innovation and Technology (DSIT) and the Department for Business and Trade (DBT) are also key government bodies that create legislation relevant to the UK's food system, and technological innovation within this system, which could be influential in promoting circular economic activity (National Food Strategy, 2021).

A key potential barrier to circular trade that was identified in the literature is trade protectionism (Barrie et al., 2022a). Since circularity is supported by harmonized and highly coordinated trade systems, trade protectionism can limit circularity-promoting activities, such as harmonized definitions and preferential free trade agreements (PTAs) for circular goods (Barrie et al., 2022a; Barrie and Schröder, 2021). Barrie and Schröder identified "harmonizing domestic trade policy with international trade" as a driver of circular trade, which would be inhibited by trade protectionist measures (Barrie and Schröder, 2021). With the UK's decision to leave the EU in 2016, which officially took effect in January 2020, trade harmonization between the UK and EU was diminished, which could pose issues for integrating greater circularity in trade relations (Bounds, 2023).

2.1.1.4 EU-UK policy

Policy established bi-laterally between the UK and EU is another key factor governing circularity of trade in the case study context. The primary trade policy in place between the two parties is the UK-EU Trade and Cooperation Agreement (TCA), which also governs agri-food sector trade. Post-Brexit the UK remains bound to regulations within the EU's Single Market established between member states when exporting products to the EU. Examples of agri-food trade-relevant measures include food safety, animal welfare, and marketing (i.e., packaging and labeling) requirements. Other policy regulations relevant to agri-food trade include technical barriers to trade, nontariff measures and at times sanitary and phytosanitary measures. The more aligned the UK and EU are in these measures, the fewer barriers to trade will exist (Jelliffe et al., 2023; Barrie et al., 2022a).

In terms of facilitating circular trade, regulatory alignment and definitional harmonization are key drivers as these measures make it easier for goods to re-circulate through value chains (i.e., machinery that is remanufactured or refurbished) with minimal bureaucratic hurdles or non-tariff barriers in place to verify that products are fit to be imported (Barrie and Schröder, 2021). Following the UK's exit from the EU, UK imports now need to pass a Conformity Assessment to ensure that they are acceptable for the EU market (Department for Business and Trade, 2022), whereas prior to Brexit, the UK belonged to the EU Single Market and was subject to the same standards as all other EU member states (Jelliffe et al., 2023). In relation to agri-food trade, given that sustainable and environmentally restorative cultivation practices are essential to circularity in food value chains, alignment in definitions for these activities would allow for greater ease in identifying equivalences and determining whether products contribute to agri-food trade system circularity (Ellen MacArthur Foundation, 2021; UNECE, 2021).

Non-tariff barriers to trade have emerged between the UK and EU following, Brexit affecting each parties' agri-food sector (David Bakker et al., 2023; Inman, 2023). Non-tariff barriers include additional requirements for goods to be inspected, regulations around product labeling, as well as additional documentation requirements (UK Parliament, 2018). Indeed, there are fewer small to medium-sized enterprises (SMSEs) in the UK exporting to the EU post-Brexit, and the UK trades less with smaller economies within the EU (Steinfatt, 2020). These trade impediments could make circularity more difficult if bureaucratic complexity increases in the trade processes (Barrie et al., 2022a). The potential for protectionism in the EU exists as well and any protectionist measures undertaken by either party may stifle circularity in trade (Burchard et al., 2019).

Intellectual property rights (IPR) access was also identified in the literature review as key driver of circularity in trade and could be influenced by policy initiatives. IPR access allows for repair and refurbishment of durable goods to occur, which were also identified as an important activity for fostering circularity in international value chains. If agricultural machinery, for instance, was produced in an EU country and exported to the UK and a user in the UK wanted to repair it to prolong its lifetime in the value chain, access to the knowledge to do so may be barred by existing IPR legislation. IPR restrictions that hinder circular economy-promoting activities, therefore would serve as a barrier to circular trade in this instance (Barrie et al., 2022a; Barrie and Schröder, 2021).

Post-Brexit, the UK's critical relationship with the EU in agri-food trade was also redefined. With this decision, the UK left the EU Common Agricultural Policy (CAP), which had previously provided financial support to EU member state farmers and shaped the types of production that were undertaken (European Commission, 2023b). Leaving CAP was a key argument in favor of Brexit by those in government who supported it (O'Carroll, 2022). In 2021, the UK-EU Trade and Cooperation Agreement (TCA) entered force. The TCA is the primary preferential trade agreement (PTA) that establishes the details of a post-Brexit UK-EU trade relationship. It eliminates tariffs on UK and EU-produced goods being imported between each party and allows for mostly free trade (Jelliffe et al., 2023). Other regulatory hurdles and non-tariffs barriers to trade have emerged, however, including within the agri-food sector, making trade with the.

While circularity in agri-food specifically is only beginning to be discussed in both the UK and EU in policy and decision-making spheres, the UK and EU have legislation in place to foster overall circularity within each respective party's jurisdiction. In 2020, the UK government announced its Circular Economy Package, and its nations have announced their own devolved commitments to economic circularity (DEFRA, 2020). Notably, the Scottish government has relatively extensive local circularity measures in place, with a Circular Economy Bill passed in 2023, and a circular economy Route Map in place (Scottish Government, 2024). Relative to the UK, the EU has

more extensive measures in place for promoting circularity within the bloc. In 2020, the European Commission passed the Circular Economy Action Plan (CEAP) under the European Green Deal (European Commission, 2023a). It includes an Ecodesign Directive that expands upon previous requirements for energy efficiency to include regulations on durability and recyclability of products manufactured in the EU (European Parliament, 2017).

2.1.2 Market factors

In addition to policy factors relevant to CT, general market dynamics also determine drivers and barriers to circularity in trade. Non-tariff barriers, which have been extensively observed between the UK and EU post-Brexit, including in agri-foods, will act as barriers to circular trade as they point to potentially problematic heterogeneity in trade policies that will make the cyclical exchange necessary to CT more difficult (Inman, 2023; Coe and Ward, 2019; Global Counsel, 2018).

Comparative advantages are also key market dynamic considerations for circularity. For instance, due to climactic differences, the EU produces a greater variety of produce items that the UK imports. Some research indicates these items from the EU results in fewer emissions than growing these products in the UK (National Food Strategy, 2021; UNECE, 2021). Circularity-promoting production and trade policies can promote the EU becoming a leading exporter of regeneratively-produced produce to the UK, for instance. The UK could also leverage its strong services sector to provide a labor force that is highly trained in delivering circularity-promoting services across values chains (UK Board of Trade, 2021; Barrie et al., 2022a).

Consumer demand is another market factor that can act as a driver or a barrier depending on how consumer preferences are shaped by cost of goods, or education and marketing campaigns. There have already been marked shifts in consumer preference for more environmentally friendly goods in the relatively wealthy, highly developed economies of the UK and EU states. Both the private and public sectors can help reorient consumers toward circular goods, especially within agri-foods through education of its benefits, as well as funding for circular producers to minimize any higher costs for consumers (Ellen MacArthur Foundation, 2021).

Overall costs associated with linear versus circular value chains also influence willingness of firms to adopt circular practices, and therefore overall circularity in trade. The long-term costs of linear economic activity are not always apparent in the price differences for circular versus linear value chains. In a report from the Ellen MacArthur Foundation on a circularity in food systems, it was found that more circular production could be more profitable than linear production methods after a transitory period (Ellen MacArthur Foundation, 2021). Indeed, in a survey of EU businesses participating in a study to determine hurdles to implementing CE practices, increased costs of these practices were cited by businesses as a key barrier to implementing them (Rizos et al., 2016).

2.1.3 Research and design

Research and design (R&D) encapsulates another key factor that can shape circularity in trade. "Research" is intentional investigation of how to increase economic and trade circularity within the case study system. "Design" refers to whether physical processes or products are designed to be circular, i.e., environmentally regenerative, or easy to repair and recycle. Literature reviewed to inform CPEs explicitly mentioned R&D key to furthering circular economic activity in terms of developing technical capacity for performing circular activities outlined in Section 1. These concepts are highly interconnected since research will often inform design (Barrie et al., 2022a; Barrie et al., 2022b; Garrido-Prada et al., 2020). Research and design can generate new technologies that facilitate CT activities (Barrie et al., 2022a). Key areas of innovation include enhancing supply chain logistics that can make data gathering more detailed and transparent. This can aid in identifying places where waste occurs in supply chains and how this waste can be avoided or revalorized (Ji-Hyland et al., 2025).

Knowledge sharing would also constitute an essential driver of circularity relevant to R&D as sharing experience of best practices could dispel some of the uncertainty that can make stakeholders less likely to adopt CE and CT measures (Rizos et al., 2016; Kirchherr et al., 2018; Eisenreich et al., 2022).

3 Methodology

The goal of this study was to create a causal loop diagram (CLD) modeling drivers and barriers to circular agri-food trade between the EU and UK. There is extensive precedent for using systems thinking to better understand complex social, economic and environmental issues (Giordano et al., 2025; Pham et al., 2024). It is especially useful for complex societal issues suffering from "policy resistance" where changing system outcomes is extremely difficult due to deeply embedded system-wide status quos, such as moving from the current linear economic paradigm to a more circular one (Sternman, 2002; Meadows, 2008). Figure 2 outlines the study design. First, a definition of CE was established to identify the activities and processes that constitute or promote CT since CE activities form the basis of CT (de Lange et al., 2022). A grey and academic literature review of knowledge on CE, CT and UK-EU agri-food trade was conducted. Table 2 shows an overview of search terms used to conduct the literature review. Literature reviewing UK-EU trade dynamics, or that commented on agri-food sector dynamics within the UK or EU, was only reviewed if published after 2020 to account for changes that occurred following Brexit.

FIGURE 2
Summary of research approach taken to determine system dynamics within UK-EU agri-food trade in terms of trade circularity (*created using Keynote*).

This analysis was firstly descriptive, with a definition of CT established in the Introduction (Section 1) of this study, then factors affecting CT and key themes regarding trade circularity in agri-foods were compiled into Conceptual Framework Elements (Section 2). The Conceptual Framework Elements (CFE) were used to organize factors that affected CT. The factors were divided into drivers and barriers and system dynamics were identified using a systems thinking approach (Meadows, 2008), A causal loop diagram (CLD) was used to visualize these interconnections (indicated by the fourth box, Figure 2). Points of potential leverage to foster greater circularity in trade between these two parties were then extrapolated (box five, Figure 2). Identification of leverage points to foster a circular transition constitutes the normative phase of this analysis or proposing paradigm-shifting interventions that could be introduced into this system for greater circularity.

3.1 Systems thinking and causal loop diagrams

Systems thinking is a framework for understanding complex real-world dynamics with numerous different parts and influences, such as circularity in the case study context (Meadows, 2008). "Systems" are defined as interconnected "elements" that come together to fulfil a "purpose" (Arnold and Wade, 2015). Under Meadows' approach, systems are composed of interconnected "elements," or the CFEs defined in Section 2 (2008). System elements were selected based on the impact they had on the target variable, CT activity in agri-foods. Meadows also states that systems have a "purpose" or "goals," which is defined here as "CT in agri-foods between the EU and the UK."

To model relationships between drivers and barriers to CT in this context, a CLD was created. CLDs are made up of variables, or "nodes" connected by arrows that indicate one-directional links between variables. A positive arrow from variable X to variable Y indicated with a "+" indicates a positive link, meaning that a change in variable X results in a change in the same direction in variable Y. A negative arrow, represented by a "-" sign indicates a negative connection, meaning that as X changes, an opposite change will occur in Y. The signs only indicate if the change occurs in the same or opposite direction of the variable that is pointed to and do not indicate whether the change is increasing or decreasing, or good or bad, i.e., beneficial, or detrimental.

Feedback loops are another key aspect of CLDs. Feedback loops represent system dynamics that "reinforce," represented by an "R," or "balance," represented by a "B," each other in a self-perpetuating, cascading manner. Reinforcing loops indicate that the factors, or nodes, involved build upon each other. For balancing loops this is the reverse, where the nodes involved diminish one another (Haraldsson, 2004). Reinforcing and balancing loops were identified within the case study context and are summarized in Section 4.

TABLE 2 Literature research to identify drivers and barriers to CT in agri-foods.

Database	Search string
DiscoverEd	CE AND trade
	CE AND agri-foods
	CE AND supply chains
	CE AND labor
	CT AND agri-foods
	CT AND supply chains
	CT AND European Union
	CT AND United Kingdom
	CT AND European Union AND United Kingdom

3.2 Defining system variables

Variables were extrapolated based on the Conceptual Frameworks Elements in Section 2. CFEs were selected based on factors relevant to circular trade in the case study per literature review of work pertaining to circular economy, circular trade and factors relevant to this activity in the UK-EU context. These were applied to the CLD model in a way that would illustrate the study's exploratory system dynamics based on current definitions of circular trade and UK-EU circularity landscape. Since the case study system was highly complex, variables were also selected based on how well they encompassed most relevant, overarching categories of activities agri-food sector circularity yielded by the literature review.

Defining the target variable was also key to establishing the connections between drivers and barriers. Through the literature review, agri-food trade could be sub-divided into three categories relevant to CT: I. Biological Product CT (CT), II. Durable Goods CT (CT), and III. CT (CT)-Promoting Services. The selection of "I. Biological Product CT" and "II. Durable Goods CT." These were informed by the Ellen MacArthur Foundation Butterfly Diagram (2019) which contains two interconnected cycles of circular economic activities: the "Biological" and "Technical" Cycles. In this study, dividing CE practices in agri-food into "biological goods" and "technical goods" was particularly suitable since agri-food supply chains are composed of "biological" components, i.e., food, and technical components, i.e., all the machinery and durable goods used to grow, process, and transport this food to consumers (Despoudi et al., 2021; Manavalan and Jayakrishna, 2019).

Furthermore, each of the three categories of EU-UK agri-food CT contained subcategories in the CLD. "I. Biological Product CT" contained "Regenerative agriculture" and "biological material CE and trade (CE/T)." The latter refers to any trade that occurs with biological materials, food products intended for human consumption, or raw secondary materials derived from food products to be used as inputs for other products, food or otherwise, such as food waste for biogas production. "II. Durable Goods CT" also contained the sub-category "Refurbishment, reuse, recycling of durable goods" which summarizes the main activities involved in CE with durable goods, i.e., those made from metal, plastic etc. intended to be used over an extended period that are not compostable. This is in line with the Ellen MacAcrthur Foundation's Butterfly Diagram that divides CE into biological and durable goods cycles (Ellen MacArthur Foundation, 2019).

A third category, "III. CT-Promoting Services" was also identified as a key aspect of CT. The service sector will especially be critical in any CT transition since a labor and workforce considerations are essential components of value chains, as reflected in Figure 1,

including agri-food value chains (Barrie et al., 2022a; IISD, 2020; Tamminen et al., 2020). Table 3 summarizes examples of different agri-food category activities in target as laid out by the Ellen MacArthur Foundation (2019) in their description of the Butterfly Diagram and in their discussion of a circular transition in food systems (2021). The CLDs in Section 4 also reflect these categories of CT activity as target variables in the CLD system.

3.3 Identification of leverage points

The identification of leverage points based on the CLD models constituted the normative phase of this analysis, or determination of how a circular transition could occur, and which systemic changes should be made to encourage circularity in the case study. Meadows defines different leverage points, ordering them from least impactful, or least likely to create system-wide change (low leverage) to those that will create more impactful, system-wide change (high leverage), which are summarized in Figure 3. Leverage points are ordered based on how extensively overall goals of a system are altered by their implementation (2008).

4 Results

The CLD in Figure 4 maps key dynamics influencing the "UK-EU Agri-food CT" node, or the target variable. Figure 4 contains 26 nodes, divided up into drivers (blue) ($n = 11$) and barriers (red) ($n = 5$) to CT activity, the target variable. Dashed lines indicate hypothetical connections between nodes to highlight that these measures are not currently in place and would require changes in the originating nodes, which will be discussed in subsequent sections. Figures 5–7 provide further detail for the reinforcing and balancing loops in Figure 4. All CLDs were produced using Apple's Keynote software.

TABLE 3 Defining CT in agri-foods.

CT category	Examples of activity or good
Biological materials (Ellen MacArthur Foundation, 2019, 2021)	Regenerative agriculture
	Trade in secondary materials from food waste
	Revalorization of food processing by-products/waste
Durable goods (Ellen MacArthur Foundation, 2019)	Machinery promoting sustainable agricultural activity
	Production, transport, processing using renewable energy
	Repair, reuse, recycling, and remanufacturing of equipment
CT-enabling services (Barrie et al., 2022a)	Consulting for circular transition
	Workforce with knowledge of CE principles
	Workforce skilled in circular value chain activities

4.1 CLD summaries

4.1.1 Overall EU-UK CT drivers and barriers

The Policy Landscape grouping encapsulates policy tiers most relevant to trade circularity in the case study context as outlined in the Conceptual Framework Elements. Connections between these policy tiers are not illustrated on the CLD for diagram simplicity, but UK and EU policy are subject to WTO rules. The "CT/E-promoting policy node" represents policy that specifically addresses circularity, which was a widely cited as a driver (Barrie et al., 2022a; Ellen MacArthur Foundation, 2021; Domenech and Bahn-Walkowiak, 2019). The connections between "Policy Landscape" and "CE/T-promoting policy" and "Governmental and private sector willingness to transition to CE/T" are dashed due to the ever-evolving nature of policy, and the fact that the WTO, UK, and EU have all taken first steps to developing CE policies, but no specifically CT-promoting policies have been implemented among these stakeholders. Therefore, the dashed lines indicate that the Policy Landscape variables have the potential to adopt CE/T-promoting policies.

The Policy Landscape also has the potential to promote "Governmental and private sector willingness to transition to CE/T." Since a CT transition is a considerable undertaking that would require extensive investment in the form of research, data gathering, and trial and error, not all stakeholders may be willing to commit to this transition under current system dynamics (Barrie et al., 2022a; Ellen MacArthur Foundation, 2021). For instance, in an investigation of barriers to CE in the EU, Kirchherr et al. found that "Lacking awareness and/or willingness to engage with CE" in the private sector was a barrier, as was already "Operating in a linear system." This highlights that a circular transition would constitute an economic paradigm shift away from the status-quo of linearity (2021). Policies such as subsidies for restorative agricultural production, investment in renewable energy, research into best practices for circular economy and trade activity arpotential facilitators of CT within agri-foods that could increase willingness of governments and businesses to adopt CT activities despite initial barriers (Despoudi et al., 2021; Paltrinieri et al., 2022).

"CE/T-promoting policies" would be created with the specific intent of fostering circularity via legislative and non-legislative actions, as well as by establishing collective benchmarks for monitoring progress and defining circularity goals. CE/T-promoting policy would foster circular research and design, indicated with a positive connection to "CT R&D," which would aid in further understanding how to best implement CT principles, as well as new innovations in increasing circularity, like new uses for food waste products, or new methods of agricultural production that meet UK and EU consumers' need for food with minimal environmental impact (Barrie et al., 2022a; Ellen MacArthur Foundation, 2021). The first reinforcing loop identified (R_1 in Figure 4) was between "CT R&D" and "supply chain data gathering," the latter of which can be defined as collecting circularity-relevant information along agri-food value chains, such as sources of waste, either biological (i.e., food waste) or durable (i.e., used machinery). Detailed information on supply chain dynamics could also help identify opportunities for greater circularity (Despoudi et al., 2021; ARUP, 2018). This is where the reinforcing dynamic between "data gathering" and "CE/T R&D" occurs, where research will reinforce data gathering on areas of greatest potential for circularity and best practices for circularity.

FIGURE 3
Diagram showing leverage points for system change according to Meadows (2008). Those on the left end of the spectrum are considered "shallow" meaning they only create superficial change in systems, and those on the right can re- shape systems more profoundly, making them "deep" leverage points.

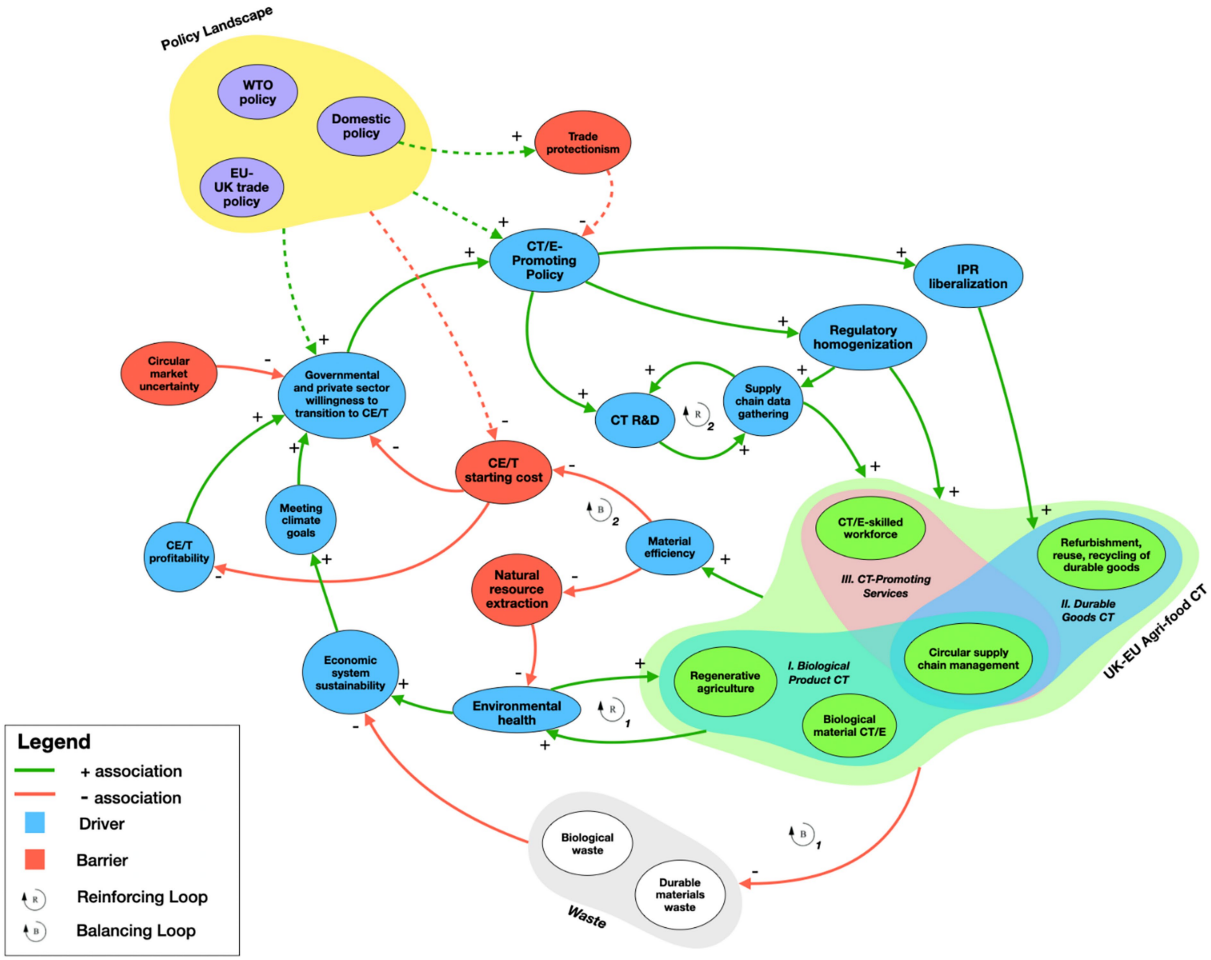

FIGURE 4
CLD of overall drivers (blue) and barriers (red) to agri-food trade between the UK and EU The target variable is "UK-EU Agri-food CT" which encompasses the three main categories of key agri-food trade activity, Biological Products, Durable Goods, and CT-Promoting Services. Positive (+) arrows increase or decrease variable arrow is pointing to in the same direction. Negative (–) arrows indicate an inverse relationship. Reinforcing and balancing loops are indicated throughout and are explored in further detail in subsequent sub sections.

For instance, ARUP et al. identified "design tools" and a "material database" as key "enablers" of circular activity. "Identifying new innovation" was also identified as an enabler, which corresponds to "CE/T R&D" in the overall system (2018). "New innovations" include "develop[ing] standards and other infrastructural facilities which will assist recycling and reverse logistics," which would also be drivers of CT related to R&D (Despoudi et al., 2021).

"CE/T-promoting policy" could also foster "regulatory homogenization," indicated with a positive connection, as the latter is a key driver identified in the literature (Barrie et al., 2022a; Barrie

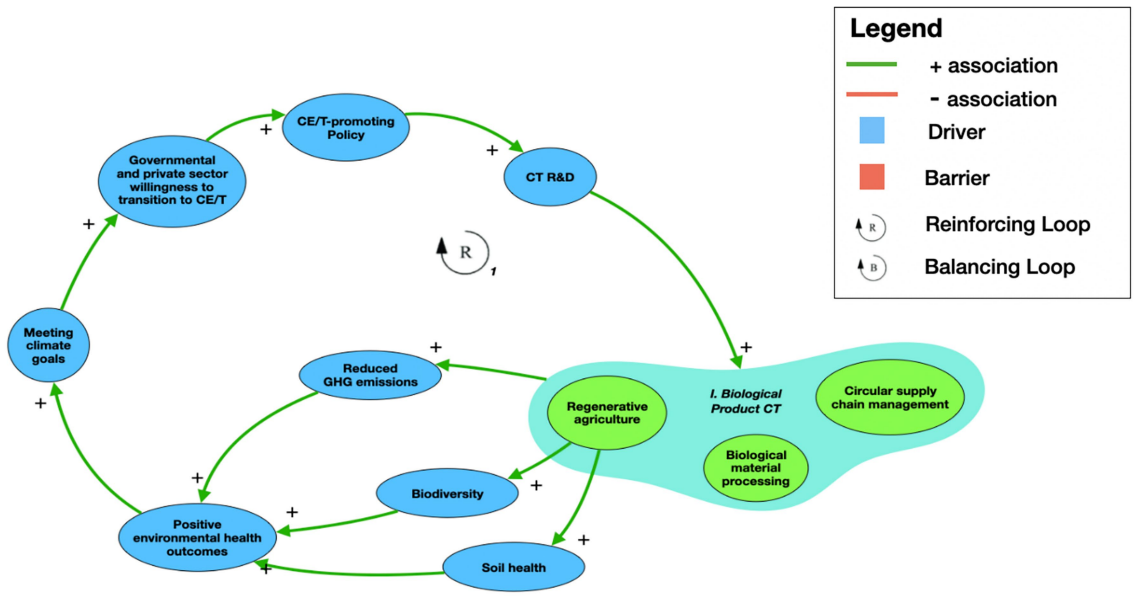

FIGURE 5
Loop reinforcing "Environmental health" and "Governmental willingness…" CE/T-promoting policy in this case study will promote regenerative agriculture, which in turn is beneficial for environmental health. If policy alignments are in place to meet certain climate goals that are tied to economic system sustainability (e.g., emissions levels) then this can incentivize the government and private sectors to be more circular (Citations in Appendix).

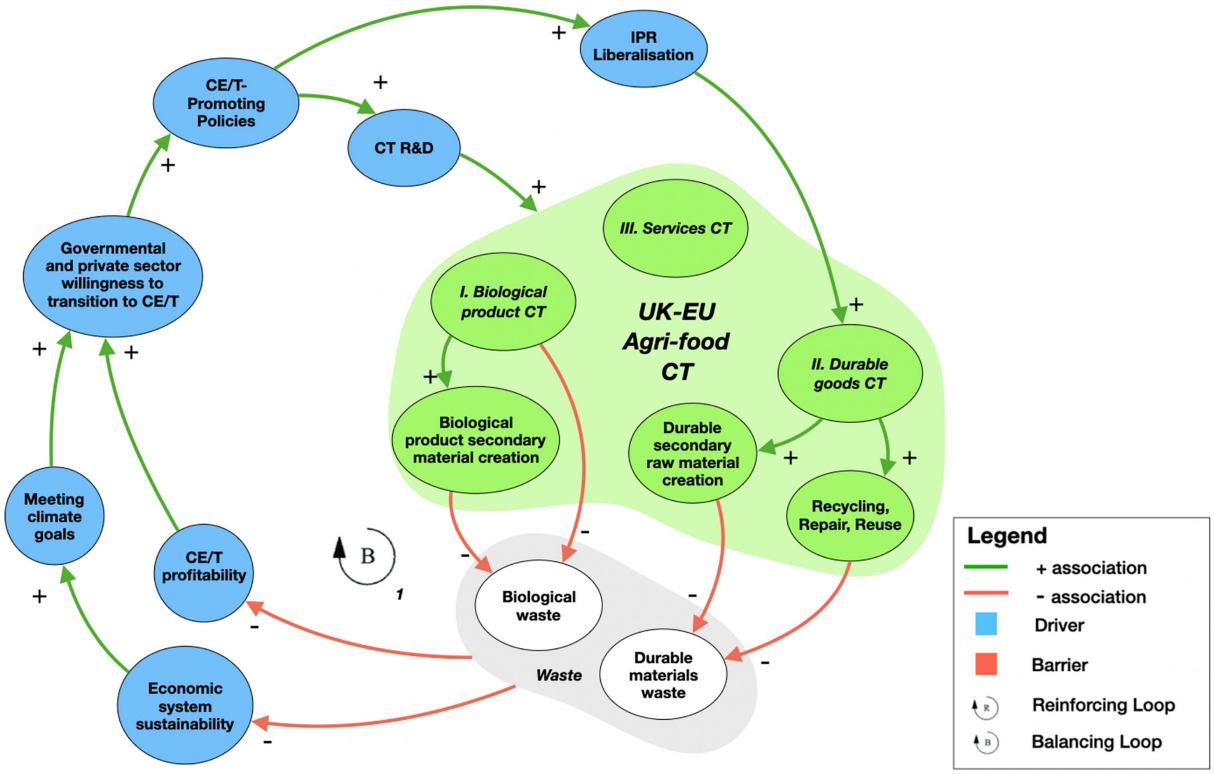

FIGURE 6
Loop balancing "waste" CT-promoting policy can promote activities that decrease waste generation in agri-food supply chains. This is done in part by revalorizing would-be waste products as raw materials for other products, preventing both waste and further extraction of resources. Decreases in waste can translate to increases in system sustainability and profitability, which in turn can make governments and the private sector more willing to transition to circular production and trade activities (Citations in Appendix).

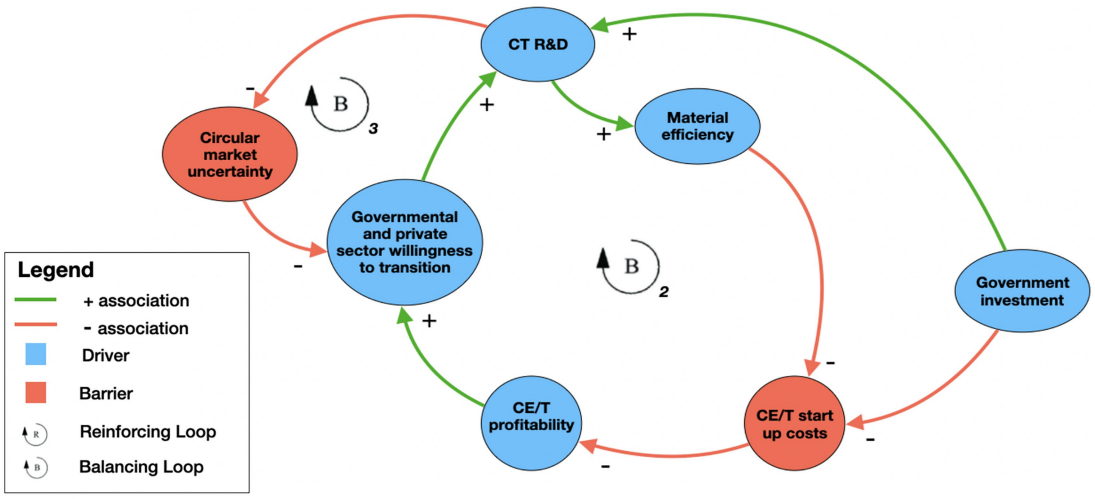

FIGURE 7
Loops balancing circular market uncertainty and CE/T start-up costs. Circular market uncertainty and start-up costs are key barriers to CT that can be mitigated through research into leveraging the greater efficiency of CT activity to decrease costs. Government investment can also help offset these costs. Research can also decrease uncertainty through the generation of data on trial and errors in implementing circularity, so stakeholders have a better sense of how to go about most effectively implementing circular practices (Citations in Appendix).

et al., 2022b; Rizos et al., 2016; Kirchherr et al., 2018). Regulatory homogenization would make supply chain data gathering easier, as standardized definitions, codes and data access would make information transfer more efficient and reduce hurdles to drawing equivalences between different processes relevant to circular activity (Barrie et al., 2022a; Rizos et al., 2016). CE/T-promoting policy could also facilitate IPR liberalization that strategically allows information sharing along agri-food value chains to promote recycling, repair, and remanufacturing efforts (Ballardini et al., 2020; Eppinger et al., 2021; Oncel, 2023). IPR liberalization is also essential to the revalorization of durable goods, which is highlighted by the positive connection between IPR liberalization and "II. Durable Goods" (Ballardini et al., 2020; Barrie et al., 2022a). Beyond machinery, regulatory homogenization could ensure that packaging, another important aspect of agri-food trade, is recyclable or reusable within the importing country. Standards for food safety and sanitation, as mentioned in the Conceptual Framework, would need to be aligned to facilitate this (Kirchherr et al., 2018).

Trade protectionism can also act as a barrier to trade circularity as indicated in the negative connection between "trade protectionism" and "CE/T-promoting policy" for its disruption to the harmonization needed to optimize CE/T activities (Barrie et al., 2022a; de Lange et al., 2022). This is also why the connection between domestic policy and trade protectionism is a dashed and positive, implying if further trade protectionist measures are adopted within this system, CT/E-promoting policy could be compromised by increased protectionism as trade protectionism would hinder CT/E policies.

Furthermore, based on definitions of CE and CT, waste reduction is an inherent result of circular activity, hence the positive arrow from "Agri-food CT" to the "Waste," which encapsulates both biological, and durable materials waste (Barrie et al., 2022a; Ellen MacArthur Foundation, 2019). Environmental health is promoted by overall circular economic activity, but particularly the "I. Biological Product CT" section of "Agri-food CT activity," which is indicated in the positive connection between "I. Biological Product CT" and "environmental health." The reinforcing dynamic between these nodes will be further discussed via Figure 4.

CT activity also enhances material efficiency, thus reducing natural resource extraction. "Material efficiency" is another key driver of eventually reducing "CE/T starting costs" (Ellen MacArthur Foundation, 2021; Vegter et al., 2020). "Material efficiency" also inherently decreases "natural resource extraction," thus indicated by the negative connection between these nodes. For example, implementing CE practices can correlate with reduced waste disposal costs, as well as decreased risks involved with disposal of waste, which in turn decrease overall costs of production (Ellen MacArthur Foundation, 2021).

Another key dynamic highlighted by Figure 4 is how waste reduces economic sustainability and CE/T profitability. Waste points to inefficiencies in resource use and corresponds with increased GHG emissions, which will reduce economic system sustainability. Economic system sustainability will also positively impact "meeting climate goals." These can serve as motivators for the private and public sector, thus positively influencing "governmental willingness to transition to CE/T" (Rizos et al., 2016; de Lange et al., 2022; Barrie et al., 2022a; Kirchherr et al., 2018).

CE/T start-up costs, however, negatively impact (−) CE/T profitability, which would otherwise be a key driver of CT activity since continued profitability of business activity is essential for its adoption (Rizos et al., 2016; Hina et al., 2022). Finally, market uncertainty was also cited as a reason some stakeholders were hesitant to undertake CE or trade activities (Kirchherr et al., 2018). This encompassed the lack of precedent for CE business models and of proven technologies to implement CE principles, and lack of certainty around labor demand if a transition were to occur (European Commission, 2018; Hina et al., 2022; Kirchherr et al., 2018).

4.1.2 Reinforcing "environmental benefits" and "willingness to transition to CE/T"

Figure 5 highlights how "environmental health" reinforces "governmental and private sector willingness to transition to CE/T" (Steinfatt, 2020). As indicated, "CE/T-promoting policies" positively connect to "CT R&D," which in turn would promote CT activity in node "I. Biological Product CT" as new and existing methods for circularly processing biological products are expanded. Within this category is "Regenerative agriculture," which promotes "environmental health" via improvements in biodiversity and soil health inherent to these practices (Ellen MacArthur Foundation, 2021; European Commission, 2023b).

Regenerative agriculture can promote a reduction in GHG emissions, improve biodiversity and soil health, which would translate to "positive environmental health outcomes" which would have a positive relationship with "meeting climate goals" (Ellen MacArthur Foundation, 2021). Climate mandates and policy-based requirements are key drivers identified in the literature. If climate and sustainability goals at the UK, EU and international levels required circularity in agricultural production and handling of waste products, this would also contribute greater agri-food trade circularity, as regeneration of nature and sustainability are key aspects of circularity in food systems (Despoudi et al., 2021).

4.1.3 Balancing "waste"

Figure 6 further emphasizes how "CE/T-promoting policy" could foster a circular transition by promoting overall waste reduction. As established, "CT R&D" is a driver of circularity, hence the positive connection between these nodes. "IPR liberalization" is particularly relevant to "durable goods CT" and connects positively to it. "CT in biological goods" would lead to increased biological secondary raw material generation, i.e., re-valorized byproducts of biological materials that can used as primary material inputs for other products, as this is a key activity in processing food items circularly (Despoudi et al., 2021; Matharu et al., 2016). The technology and best practices for this revalorization along food value chains would be informed by CT R&D. Once these revalorization practices are implemented, both biological and durable waste will decrease as valorization occurs (Ellen MacArthur Foundation, 2019). A reduction in waste could result in savings for businesses that could correspond to an increase in profitability, though this would need to be carefully weighed with other circular transition costs and will be discussed further in Section 5. Cost savings associated with circular practices could translate to an increased willingness to transition, hence the positive connection indicated in Figure 6.

4.1.4 Balancing "circular transition costs" and "uncertainty"

Despite some existing efforts in fostering circularity in UK and EU agri-food value chains, circular starting costs and uncertainty were identified as key barriers to a circular transition in the literature review and are summarized in Figure 7 (Ellen MacArthur Foundation, 2021; Kirchherr et al., 2018). In the longer-term, costs can be offset by "CT R&D" aimed at increasing material efficiency to decrease "CE/T start-up costs" over time, indicated in Figure 6. Government grants for CE/T activity could aid in offsetting these costs in the shorter term while producers and businesses along the food value chain initially adopt circular practices (Ellen MacArthur Foundation, 2021; Ghisellini et al., 2016). A decrease in "CE/T start-up costs" would lead to an increase in "CE/T profitability," making this loop ultimately balancing of "uncertainty" and "costs" though the connection between "CE/T start-up costs" and "CE/T profitability" is negative. Economic viability of adopting CE/T practices would in turn contribute to an increase in the "willingness" node and then further reinforce "CT R&D" as efforts to refine best practices around CE/T would need to continue. This is further illustrated by the balancing relationship (B_3) between "CT R&D," "circular market uncertainty" and "willingness." "CT R&D" can also decrease market uncertainty by generating quantitative evidence of waste reduction, revenue etc. related to CT activity, something which is currently lacking and makes businesses hesitant to commit to circular activities (Kirchherr et al., 2018), including within the agri-food sector in the UK and EU (Kuch, 2022; Ellen MacArthur Foundation, 2021). Therefore, as more information is made available on how to most efficiently engage in CT and maximize monetary and environmental benefits, uncertainty would decrease, thus positively impacting overall willingness of stakeholders to transition to CE/T (Eisenreich et al., 2022).

4.2 Key leverage points

Figures 4–6 indicate key leverage points where interventions would be most effective promoting a circular transition in UK-EU agri-food trade. Discussion of leverage points also constitutes the "normative" phase of this analysis. "CT-E Promoting Policy" is one of the most impactful leverage points given that it drives three other highly impactful nodes, "CT R&D," "Regulatory homogenization," and "IPR liberalization." Policy in the case study system can re-shape "system goals" which is considered a deep leverage point on the spectrum represented in Figure 3 (Meadows, 2008). Making a "CT transition," or "increasing CT transactions" between the UK and EU in agri-foods would require CT-promoting goals that could be reached through policy change. For instance, a circularity clause in the UK-EU Trade and Cooperation Agreement (TCA) would be an impactful intervention for facilitating circular trade activity in this case. Such interventions could have a cascading effect, where commitments to invest in CT R&D are established alongside IPR legislation that strategically facilitates the sharing of information that would advance reuse, repair and recycling of durable goods used in agri-foods. This corresponds to Meadow's leverage points of re-orienting system goals, which is a deep leverage point with potential of effect significant system-wide change, outlined in Figure 6.

Regulatory homogenization could also be achieved by setting standardized definitions and codes for trade in circularity-enabling goods. Such measures could also promote supply chain data gathering that tracks the movement of products to identify ways in which waste can be reduced (WBCSD, 2023). This would constitute a key "Information flow" as a leverage point that would correspond to "rules" around amounts of waste that are considered acceptable within the system. Legal requirements, or rules, were cited by Kirchherr et al. (2018) and Despoudi et al. (2021) as key motivators for businesses to adopt circular practices despite the cost of doing so. These mid-level leverage points could contribute to the deeper leverage point of "System goal" for a circular transition in trade between the UK and EU.

WTO policy can also significantly shape circularity in agri-food trade in the case study. In 2014, discussions regarding an Environmental Goods Agreement (EGA) occurred between certain WTO members, including the EU, which included the UK at the time. An EGA would be a designation for products that promote sustainable economic practices (WTO, 2015). This approach could be applied to circularity-promoting goods via preferential trade agreements. This designation could also help facilitate preferential tariffs for circularity-enabling goods that could enhance CT in agri-foods.

Increasing CT R&D is another key leverage point that emerged in this analysis. The current lack of quantitative data and research regarding circularity in agri-foods (Kuch, 2022; Ellen MacArthur Foundation, 2021; UNECE, 2021) means there is considerable ambiguity for next steps for governments, businesses, and consumers in terms of making decisions around their role CE and trade (Ellen MacArthur Foundation, 2021). The creation of a monitoring framework, such as the one within the EU's CEAP, could create a key information flow within the context of the broader system goal of transitioning to a circular agri-food trade system. This constitutes a "self-organizing" leverage point since a with a monitoring framework, the system will also have guidelines for making changes to itself, especially if the shallower leverage point of "rules" supports this monitoring activity to advance circularity goals, such as requiring agri-food businesses to track waste quantities.

The combination of policy and CT R&D for a circular transition can also activate the "physical systems" leverage point, which refers to how physical systems are managed. This would include agri-food supply chains, from agricultural production to processing agri-food goods, as well as managing waste throughout the supply chain. Altering these physical systems to carry out circularity-promoting activities would be a key contributor to overall agri-food system circularity (Meadows, 2008).

5 Discussion

This study highlights the complexities of introducing circularity into UK-EU agri-food trade, which would affect many aspects of this sector. Though both parties' governments have voiced intentions to enhance circularity in their respective economic systems, few concrete measures to promote CT have been implemented and none at the time of publication have been implemented bi-laterally between the EU and UK. This study firstly indicates a need for intentional, circularity-focused policy action to lay the foundation for other key CT-promoting activities highlighted in this study, namely research and design, information and knowledge transfer, supply chain tracking, and expansion of the circularity services sector. Given the barriers to CT, primarily having to do with transitionary costs and uncertainty, efforts to bring about circularity must be explicit in their goals and use circular economy-specific language and frameworks.

At the highest level of policy, the WTO could leverage its sustainability-focused working groups to promote trade circularity and foster homogeneity in trade policy around goods that promote circularity. Establishing definitions of "circular goods" at all levels of policy would also begin to codify circularity approaches and simplify and encourage trade of circular products. The EU CEAP includes a "digital product passport" that contains information relevant to circularity (i.e., origin, production methods etc.) (CISL and Wuppertal Institute, 2022). Such interventions could be applied in the UK as well, and if definitions are harmonized with those in the EU, this could foster circularity of products traded between the two nations. The UK and EU could also add a circularity clause to the UK-EU TCA, or add language around circularity, something which has already been done around trade of organic food, where there is equivalency between UK and EU definitions of "organic" (European Commission, 2023b). Organic designations overlap somewhat with circularity approaches to food production, but could be expanded to specifically foster circularity, acting as a higher leverage driver of CT.

A relatively actionable information gathering intervention that could occur under current system dynamics would be quantification of waste flows throughout the agri-food value chains in both the UK and EU. Measuring waste among producers, food processors, retailers, and consumers could provide quantitative feedback for points of intervention in a circular transition. Quantitative data on waste flows is currently lacking and contributes to uncertainty around circularity approaches, which was cited as a key barrier to circularity (Barrie et al., 2022a; De Lima et al., 2021). Some food retailers have begun to track their waste, and there is a growing awareness of the issue of food waste among consumers (WRAP, 2023) but a more systematic approach overseen by the UK and EU governments could accelerate this process.

The high-leverage power of "system goals," where circularity in trade as a goal set by governments and the private sector will also be essential to a circular transition. Conducting research on how to engage with consumers around circularity will also be key to ensuring the long-term financial success of a circular transition and overcome company hesitance to adopting circular production practices. Despite the relatively little research in agri-food trade circularity, the WTO and UNECE have stated that greater trade circularity is essential to ensuring the continued food security of Europe, including the UK and EU. Expanding research efforts specifically geared toward developing best practices in CT in agri-foods will also be key to easing uncertainty and incentivizing businesses and other key relevant stakeholders to make this transition.

This study also indicates multiple areas where research efforts should be diverted. Labor implications of a circular transition in agri-foods will be essential given that a circularity-proficient service sector will be critical to fostering and performing circularity. The literature review yielded little information on this sector not only regarding agri-food circularity, but overall CE transitions. Indeed, given that little information currently exists on circularity in agri-food trade, these results are highly generalized and do not take into account differences between different EU states that may be relevant in this context. Some research exists regarding CT between "unequal" trade partners, i.e., a developed and less developed nations, but this should extend to the European context, where differences are less stark than, for instance, CT between the most highly developed nations in the world, and the least. Furthermore, the trade relationship between the UK and EU will continue to evolve as the UK defines its national, devolved, and international policies around agri-food value chains and as continued discussions of the UK-EU trade relationship occur.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

AN: Writing – review & editing, Writing – original draft. LT: Supervision, Writing – review & editing, Writing – original draft.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/frsus.2025.1623085/full#supplementary-material

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