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# Global circular networks and couplings: Exploring the global architecture of the circular economy

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## Abstract

Geographical research on the global economy has largely failed to conceptualize processes of circular change, while geographical issues are rarely considered in scholarship on the circular economy. Therefore, in this paper, we conceptualize a globally integrated circular economy and identify the key mechanisms of circular (de-)couplings. We provide a novel framework for understanding these changes by combining four essential dimensions - actors, resources, functions and geography - which we illustrate with empirical examples. This can inform human geographic research approaches to the topic and policy making at different levels on how to rethink global entanglements and drive circularity-oriented changes.

**Keywords**: circular economy, global economy, global production network, global value chains, transitions

**JEL Codes**: F63, Q01, O19,

# 1 Introduction

Global production of goods, organized in global production networks (GPNs, e.g., Coe & Yeung, 2015), has been identified as a major contributor to climate change, environmental degradation, resource depletion, and uneven global development (e.g., Meng et al., 2018; Ponte et al., 2023). These networks have enabled and served the linear economy i.e., the dominating take-make-waste logic across space and scale, and manifested the global production model as the architecture for linear product flows. A key question for the present and the future is how these networks can become more sustainable, which fundamentally challenges their linear logic. This concerns in particular their resource flows[1] in production and consumption processes, thereby relating to aspects such as material footprints, throughput, and emissions as well as their changing geography. In this regard, the circular economy (CE) - as opposed to the linear economy - is increasingly seen as a means to drive such sustainable change. It is considered an alternative model for economic processes and organization, represented in the circulation of resources as a driving metaphor (Geissdoerfer et al., 2017; Korhonen et al., 2018). The concept is prominently favored in policy strategies and academic research to successfully combine the goals of economic development (growth) and environmental sustainability. Furthermore, multinational companies (MNCs), such as H&M, Renault, Unilever and others[2], are increasingly articulating a circular orientation of their global operations and processes in, among others, strategic documents, which could eventually affect the geography of their operations.

Against this backdrop, the question arises as to how circular changes in GPNs, that are necessary for more sustainable outcomes, can be theorized and situated within geographical thinking. Two key research fields seem to be relevant for this: research on GPNs (e.g., Coe et al., 2004; Coe & Yeung, 2015; Henderson et al., 2002) and the CE (e.g., Geissdoerfer et al., 2017; Korhonen et al., 2018). Both research fields lack a conceptual understanding and integration of key mechanisms relevant to circular changes in these global networks. Moreover, due to opposing logics (linear – circular), and different implied geographies, it is not evident if and how empirical changes could be possible. On the one hand, research on GPNs has been silent on issues related to sustainability or a CE (Coe & Gibson, 2023). While this could result from a lack of empirical cases from which to theorize, it also points to conceptual blind spots and ontological traditions. This is different in the adjacent field of global value chains (GVCs), which has developed the notion of environmental up- and downgrading to account for sustainability-based shifts that result in lower or- higher value-added positions (e.g., Krishnan et al., 2022). However, research on GVCs is less spatially attentive to multi-scalar contexts and comes with a linear chain metaphor, which is why we believe this concept is less suitable than the GPN concept in terms of identifying and problematizing relations with the CE literature. On the other hand, the research field of the CE largely lacks a spatial perspective, one that understands the geography of circular changes, how this relates to globally integrated economic processes and the multi-scalar architecture of circular trajectories. Among the rather few geographical contributions to the vast and quickly expanding CE literature (e.g., Bourdin & Torre, 2024; Davies et al., 2024; Deutz et al., 2024; Hobson, 2015; Meili et al., 2024), a global perspective that acknowledges the significance of the functional integration of economic activities in GPNs is rarely taken. Rather, the CE is often understood as a local or regionally-oriented form of economic process.

[1] In this paper, we use the term ‘resource flows’ to account for material and energy that are used and transformed in the production and consumption of goods.

[2] For recent examples of multinational firms, see https://www.ellenmacarthurfoundation.org/circular-examples-collection-multinational-companies, 2024-12-19

In this paper, we take the perspective that any consideration of the CE must take into account the existing global architecture of the economy in GPNs, from which these processes would have to evolve. While we can perceive a spatio-temporal rescaling of the economy (Grillitsch et al., 2024), we find it difficult to imagine an absolutely deglobalized world, given the many aspects of everyday global life and infrastructures. Therefore, there is a critical need to conceptualize and develop the interrelationships between the CE and the global economic architecture to unlock circular potentials. In this paper, we pursue this novel conceptual endeavor, cultivated in an in-depth discussion and problematization of the *assumptions* (cf. Alvesson & Sandberg, 2011) that characterize both GPNs and the CE as research fields, and that relate to differences in both epistemological origins and ontological traditions. We integrate key assumptions from both literatures and develop a framework of 'global circular networks' rooted in a functionalist understanding of the geography of these networks. We furthermore conceptualize the mechanism of 'circular (de-)couplings' as the necessary dynamic that characterizes a shift from the global linear economy to the global CE. This mechanism describes how existing GPNs are being transformed into global circular networks, based on couplings with circular functions. This is meant to provide a conceptual toolbox for understanding how circular transitions from GPNs dominating the linear paradigm could unfold in a multi-scalar architecture and how this can be empirically explored. We pose the following research questions:

- *How can a globally integrated circular economy be conceptualized?*
- *What are the central mechanisms of a global circular economy and how can these be researched empirically?*

The paper is organized as follows. We first describe the assumptions that characterize the GPN and CE research fields (section 2), before conceptualizing a globally integrated economy (section 3) through the notion of global circular networks and in particular the central process of 'circular (de)couplings'. We then illustrate these considerations in brief empirical examples of couplings (section 4) that are meant to inspire empirical research on this topic. We close by drawing conclusions (section 5) for the emerging field of the geography of the CE.

# 2 Assumptions and limitations of GPNs and CE

## 2.1 Assumptions characterizing the GPN literature

When the concept of GPNs was developed by Henderson et al. (2002), it was characterized by carefully chosen considerations of using the word 'global' instead of 'international' and 'transnational' to break with state-centric discourses. Furthermore, it is considered that the functional integration of activities in GPNs, following globalization, reflects a qualitatively different phenomenon to previous modes of production. The concept developed a focus on immaterial flows (value, knowledge, and power) in multi-actor settings which are driven by different motivations. The metaphor of networks is central, which embraces vertical and horizontal integration. It is rooted in multi-scalarity (thinking about places in horizontal and vertical integration), a linear economy with a one-flow direction of materials, goods, and products (Herod et al., 2013), and relationality (actors need to be considered in relation to each other), shaped by the idea that globalization is a conducive condition for economic growth and prosperity, while not considering material resources as a constraint. Consequently, a driving assumption that emerged from early work is that understanding globalization (and especially post-Fordism) requires a shift in the analysis of the economy towards an understanding of the global processes and architecture of economic relationships (Henderson et al., 2002). Coe et al. (2004), consequently, operationalize this by focusing on MNCs (lead firms) as central actors

and assume (strategic) couplings (the functional integration of regions in the global economy) as a necessary condition for regional development. This work thus perceives MNCs as superior to other firms, states, and regions, being flexible in their spatial choices. Power relations at the state-firm nexus, between MNCs and regions, and between MNCs and other firms have become a central aspect in the analysis of global relations, while couplings become a central metaphor and mechanism. Power is considered to lie mainly with lead firms, while states provide and constitute institutional environments.

The normative orientation of GPN research is to promote economic growth in regions and states, which could be achieved through three main mechanisms value creation, enhancement, and capture, as well as the exploitation of scale and scope economies. GPNs emerge as a research field that assumes a global competition between regions and states in order to attract MNCs, and which assumes the opportunity for endogenous growth (Coe et al., 2004). In 2014, Yeung and Coe (2014) introduce what they call GPN 2.0, an approach that reconceptualizes GPNs to respond to criticisms of a static approach that explains diverse outcomes and embraces developmental concerns. Inherent in this is the assumption that GPNs shape development outcomes and that they are characterized by rational economic actors bargaining in markets and their competitive dynamics. As a result, GPNs are understood primarily through lead firms and from a micro-perspective of their actions and interactions (Yeung & Coe, 2014). In the following years, couplings as a central metaphor received continued attention and nuance, with Yeung (2020) describing different forms of coupling (i.e., organic, functional, structural). *Structural couplings* refer to situations in which "external actors connect the region into [GPNs]" (p. 184), while *organic couplings* describe situations in which "regional actors reach outside their home region to construct [GPNs]" (p. 184), and *functional couplings* describe the process by which "regional actors productively meet the wider needs of [GPNs]" (Coe & Yeung, 2015, p. 184). Recent contributions have further developed this notion discussing MNCs 'decoupling' from regional economies due to geopolitical change and instability (Blažek & Lypianin, 2024; Pavlínek, 2023). Nowadays, these different forms of couplings that form the functionally integrated global economy and how they are negotiated at the state-firm nexus are considered a central mechanism and analytical category of GPN research. This has led to the assumption that regions and states need to exploit their techno-economic capabilities and institutional environments in order to attract MNCs and create strategic couplings, and through this create economic development. Based on this, the notion that GPNs are critical to regional development has matured and become a field assumption within economic geography and beyond.

However, throughout the years of GPNs development and application in economic geography, it has also faced considerable criticism, and a variety of perspectives and extensions have emerged (e.g., Bair & Werner, 2011; Ibert et al., 2019; Kleibert et al., 2020; MacKinnon, 2012; McGrath, 2017; Werner, 2016, 2018, 2020). Among these, MacKinnon (2012) criticizes the neglect of uneven power relations and the path dependency and lock-in of existing (strategic) couplings in the GPN literature that create specific spatio-temporal configurations of possibilities for regional development. MacKinnon (ibid.) argues that it is important to include a perspective on regional variety that is situated in an evolutionary paradigm to account for the organic – rather than purely strategic – nature of couplings. He goes on to argue that recouplings and decouplings in GPNs can be understood as a link to uneven development, as e.g., decouplings refer to MNCs leaving regions, translating into socioeconomic losses. While other authors have raised issues related to the 'inclusionary bias' (Werner, 2016) of GPNs and the lack of engagement with dissociations (Ibert et al., 2019), we witness a general lack of engagement with the directionality of GPNs apart from a focus on economic development and growth. This is pertinent in a lack of studies that mobilize a GPN perspective to understand

sustainability-oriented shifts in the global architecture of the economy. Consequently, there is a severe lack of knowledge of how these directed processes can unfold in a multi-scalar architecture and what their central mechanisms are. This is unfortunate against the backdrop of ongoing environmental and climate change and asks for novel contributions that are able to conceptually embrace sustainability- or circular-oriented reconfigurations in the global economy that might involve spatio-temporal rescalings of economic relationships (Grillitsch et al., 2024). We will return to this issue in section 3.

## 2.2 Assumptions characterizing the Circular Economy literature

Although the concept of CEs has more recently attracted the attention of scholars with a booming number of published articles (Calisto Friant et al., 2020; Kirchherr et al., 2017), its core message and metaphors of 'closed loops' and 'circles' date back to the 1970s and 1980s (Geissdoerfer et al., 2017; Pearce & Turner, 1989; Stahel & Reday, 1976). In contrast to GPNs, the CE focuses on material flows and proposes a regenerative and restorative system of production (Calisto Friant et al., 2020; Geissdoerfer et al., 2017). Within a CE, power is considered to mainly lie with governments and companies (Geissdoerfer et al., 2017), and the idea of the CE has been strongly developed within these groups. Both the EU (e.g., European Circular Economic package of 2015) and individual states within Europe (e.g., Germany with its Closed Substance Cycle and Waste Management Act of 1996) as well as China (e.g., Circular Economy Promotion Law of 2008) have adopted the concept into policies. This also influences how the concept is used and understood. CE is often perceived as a 'toolbox' to address sustainable development (Leipold et al., 2022) and is "expected to solve problems of resource scarcity, biochemical flow disruption, and climate change, all while revitalizing local and regional economies" (Calisto Friant et al., 2020, p. 1). A focus on economic prosperity is particularly common in definitions used by practitioners (Kirchherr et al., 2017), and the beneficiaries of the CE are seen as the economic actors who implement the system (Geissdoerfer et al., 2017). For example, as CE is expected to extend the life of products through e.g., services, employment is expected to be positively influenced in places of consumption (such as Europe), while places of production (such as Asia) may be negatively affected by both reduced sales and employment (Skene, 2017). The idea that the understanding of CE is largely practitioner-driven is a common assumption and is an important backdrop when understanding how scholars perceive and problematize the concept.

As mentioned above, the metaphors of closed and open loops (or loop economy) and circles are recurring in the scholarly CE literature (Calisto Friant et al., 2020; Corvellec et al., 2021; Geissdoerfer et al., 2017; Korhonen et al., 2018). So is the 'waste hierarchy' and the 'R's framework' (with different R's such as Reduce, Reuse, Recycle, and Recover) (Kirchherr et al., 2017; Korhonen et al., 2018; Reike et al., 2018). However, the concept of CE is also considered to be ambiguous and encompasses different meanings (Kirchherr et al., 2017). Some scholars see this in a rather positive light (Leipold et al., 2022), in the sense that it is adaptable and promotes creativity. Others instead perceive it as negative, as it leads to difficulties in measuring circularity and that the lack of a clear definition risks leading to the presentation of only win-win solutions (Corvellec et al., 2021). The latter makes it possible for firms to 'adopt' CE with minimal changes (Kirchherr et al., 2017) or even 'greenwash' their developments and thereby stabilize existing unsustainable economic organizations (Niskanen et al., 2020). This ambiguity also means that there is less coherence in the underlying assumptions compared to GPNs, as a theoretically mature research field strongly anchored in disciplinary research. One assumption is that the CE and its focus on material flows, the waste hierarchy, and growth opportunities will be central in the future (Korhonen et al., 2018). Others focus more on the CE as a means to sustainable development (Geissdoerfer et al., 2017; Leipold et al., 2022), implying a broader goal for which the CE can be a tool. Inherent in the idea of the CE is that

CE develops at the micro- and meso-level in the form of local and regional economies. Yet, the macro level is increasingly gaining attention as CE is complex and requires systemic changes (Kirchherr et al., 2023). In the development of CE, actors' intentions may misalign. For example, the promotion of a local- or regional CE may be constrained by policymakers operating at higher scales or by firms' prioritizing a commercial view over regional embeddedness (Newsholme et al., 2022).

There are also a number of more critical voices that argue that the CE has strong limitations, both based on the idea that the CE neglects established knowledge (Corvellec et al., 2021) and will not be able to deliver enough (e.g., related to biodiversity conservation) (Calisto Friant et al., 2020) and that it is based on conflicting ideological values (such as degrowth vs. capitalism) (Calisto Friant et al., 2020). The concept of CE brings together different disciplines such as industrial ecology, economics, and other social sciences, which further shatter shared assumptions. According to Corvellec et al. (2021, p. 422), the CE concept suffers from "a perceived lack of paradigmatic strength" and should therefore focus more on its core, i.e., closed material loops and a fairer distribution of resources.

To summarize, the flora of scholarly definitions and diverse contributions to the CE scholarship opens for criticism from various directions. It is also pointed out that the theoretical foundations of the CE need to be further developed (Calisto Friant et al., 2020), especially with regard to its theory of change (i.e., where and how change occurs). The idea that CE is a means to sustainable development is shared among many, but the link between the two is criticized for being unclear (Geissdoerfer et al., 2017) and vague (Kirchherr et al., 2017). When considering the concepts of CE and sustainable development as a complementary pair, the CE literature is criticized for prioritizing economic goals. This may bring environmental benefits, but risks underestimating the importance of the social dimension (especially issues of governance, justice, and cultural change) (Calisto Friant et al., 2020). Despite being generally sympathetic to the CE, Korhonen et al. (2018) identify several limitations and challenges: the material limitations of complete recycling, linked to thermodynamics laws, and the consequent need to induce resources (energy) even in recycling, risks of shifting problems along the value chain or product life cycle and with different time horizons (i.e., rebound effects, Jevons paradox), the limits imposed by the physical scale of the economy, the tendencies of path dependency to favor the first innovations rather than the best, the limits of governance of inter/intra-organizational management, and the implications of the social construction of the concept of waste.

### 2.3 In search of the conceptual tools to study a global circular economy: Comparing GPN and CE literature

The analysis of assumptions underlying the two concepts demonstrates both similarities and differences. In terms of similarities, both concepts regard economic growth as foundational for development. Since the concept of CE is tightly connected to the normative ambition of counteracting the negative effects of previous and current production and consumption patterns, the continued assumption that economic growth will be a driver of change has been challenged, especially connected to the assumption that CE will provide a pathway for facilitating 'green growth' by decoupling resource use from economic growth. Whether this is actually possible remains to be determined in future assessments and is contested, particularly in degrowth studies (Hickel & Kallis, 2019). Moreover, both concepts identify similar key actors: firms and states. Regarding firms, GPN focuses on MNCs or lead firms while the CE also embraces novel actors like start-ups. Regarding the state, the GPN literature gives importance to the state for setting the regulatory environment in which MNCs operate. Yet, the literature also suggests that states and MNCs negotiate terms, foregrounding the importance of

power relations between these actors. The CE literature instead emphasizes the state's role as essential for providing incentives and regulations to promote the shift to circular business models. Finally, both concepts fall short of taking the role of the consumer seriously. In the case of GPN, the analysis ends with the final product. Who uses the product, for how long, and what happens with the product when it is turned into waste is of less interest to GPNs. The CE embraces the whole life cycle of the product, from sourcing, production, and consumption to circulation. Yet, many contributions still underplay the role of the consumer and of historically institutionalized consumption practices by their focus on entrepreneurial and business activities and often somewhat implicitly consider consumers as passive adopters, rather than active agents (Hobson, 2015).

While there are indeed similarities between the concepts, we have also identified key differences: First, GPN literature focuses on economic relations and value creation, whereas CE is very much concerned with material flows. Neglecting the material flows, the GPN literature lacks analytical purchase to study material use and thus environmental outcomes. Second, the temporal dimension is another difference between the two concepts. The CE is essentially prospective and forward-looking as currently there are few cases of a CE, notwithstanding rather small-scale and limited examples. The GPN literature investigates what has happened with the aim of identifying the causal mechanisms and drivers for the functional integration of economic activities globally. Third, a central difference between the two concepts is the spatial understanding of production. The GPN literature takes a global approach, embracing a multi-scalar architecture of networks and institutions. Firms benefit from economies of scale, specialization, and a global division of labor. In a linear mindset, products are produced where it is cheapest and then shipped off to consumers. In a circular mindset, the scales of production, distribution, consumption, and circulation are often assumed to be smaller and regionalized. This mismatch in geographic focus between the two remains to be conceptually addressed, leading to questions such as: At what scales is it possible to create circular supply chains? How can CE better incorporate multi-scalarity? Can circularity be realized within GPNs? In the next section, we attempt to scrutinize insights into these aspects by conceptualizing a globally integrated CE.

## 3 Conceptualizing a globally integrated circular economy

In this paper, we introduce the notion of globally integrated CE, which we define as an economy that has *established functions* necessary for *eliminating, reducing, or minimizing the use of (virgin) resources* through resource loops organized at *different spatial scales*. We argue that it is necessary to theorize, conceptualize and analyze the CE as globally integrated despite the often implicitly held assumption that the local and regional scale is particularly important for economic relations in a CE. The argument for a globally integrated CE does not neglect the importance of local and regional resource loops or regional supply chains. However, it appreciates the global integration of the economy, which is the result of globalization embedded in a neoliberal regime since the 70s (Naidu et al., 2020). Globalization describes an increasing spatial division of labor (Massey, 1995) where regions around the world develop narrow specializations and fulfill specific functions in GPNs (Dicken, 2015). This leads to 'spatial fixes' with variegated social, economic, and environmental outcomes. Also, the policy and regulatory framework, which underpinned the era of neoliberal globalization, has been ignorant about the sustainable use of virgin resources, energy as well as waste handling. As the extraction of resources, transportation, energy, and the disposal of waste was cheap and, in many places, unregulated, globalization thus provided perfect incentives for the linear

economy, and consequently led to negative environmental and social impact (e.g., Meng et al., 2018; Ponte et al., 2023).

Notwithstanding these negative outcomes, the spatial division of labor and specialization allows for technology development, international knowledge sharing, and integration of smaller and emerging economies (OECD, 2021), which will presumably also be important for development and prosperity in a CE. And while the 'extractive frontiers of capitalism' seem to be mobile (e.g. Riofrancos, 2023 for the case of lithium mining in the global North), there is also a spatially specific distribution and availability of virgin resources (e.g., rare earth minerals) that makes global processes a necessary condition for the production of certain goods. In addition, pathways from the current linear economy towards a CE cannot be studied, understood, or affected if we ignore its starting point, i.e., the current globally integrated economy. This requires theories and concepts that give prominence to the flow and use of resources in a globally integrated economy. Effectively, we argue that this can be done by studying the functions of the current linear economy and investigating, which additional – or substitute – functions are necessary to generate resource loops (see Table 1). These resource loops can be organized at different spatial scales and emerge within a multi-scalar architecture, which will be conditional to particular material and technological aspects – and can be studied empirically.

The transition from a globally integrated linear economy to a globally integrated CE can be understood through the dynamic mechanism of what we denote as 'circular couplings' as new functions and potential decouplings from existing functions (see section 3.1). The resulting construct that emerges from these couplings is what we call a *Global Circular Network* (GCN). We use this term to account for the qualitative difference between GPNs and GCNs and the lack of an existing conceptual vocabulary that takes into account the relevant aspects such as actors, functions, and resources (see section 3.2) in the formation of these networks.

### 3.1 Circular (de-) couplings and added functions

As we have outlined above, a globally integrated CE presents novel spatio-temporal configurations of economic processes that go beyond the realm currently discussed by the CE and GPN frameworks. A central aspect of this shift, so we argue, is the mechanism of *circular (de)coupling*. Thereby, we start from the observation that a globally integrated CE will be formed through mechanisms similar to those that are described in classical GPN work (see section 2.1). However, since the CE is a directed economic process, we consider circular couplings to comprise processes by which the strategic direction of lead firms to pursue a CE is aligned with regional interests, resources, needs, and capabilities, including the circular missions of these regions and the activities of actors other than firms. This can for example relate to what is discussed as functional couplings, where regional functions (i.e., techno-economic capabilities and resources) match the (circular) economic interests of lead firms. Thereby, for example covering the process by which lead firms strategically couple with a region because of the availability of specific recycling facilities (e.g., the dairy company ARLA partnering with the recycling company Südpack for the recycling of mozzarella cheese packaging)[3]. We can also think of organic circular couplings, where regional actors reach outside their context to create novel GCNs (e.g., how waste products from ARLA are being used as resources (energy) in the unrelated start-up Enorm's production of animal protein or how recycled Tetra Pak packages (polyal) becomes new products at IKEA). These processes may also be a consequence of existing couplings being recoupled (for other purposes, such as a CE orientation) i.e., instances in which the purpose of existing couplings is being

[3] See online: https://www.arla.com/company/news-and-press/2023/pressrelease/from-the-incinerator-to-new-packaging-arla-foods-explores-new-way-to-recycle-plastic-waste/, 2024-12-19

reconsidered. This e.g., relates to situations in which existing economic facilities are getting repurposed in light of circular changes (e.g., an old Renault factory being repurposed into the Re-factory)[4]. Circular decouplings, on the other hand, describe situations in which regions and/or lead firms no longer consider existing couplings to be viable for the strategic goal of a CE, or consider other functions to be relevant, and consequently cut them. This can for example relate to situations in which firms implement circular processes (e.g., reuse) through which they can substitute new input materials and decouple from the provider of these materials. Thus, taken together, these (de-)couplings are the *necessary dynamics* for the transition from a globally integrated linear economy to a globally integrated CE (see Figure 1 for a schematic depiction of these couplings).

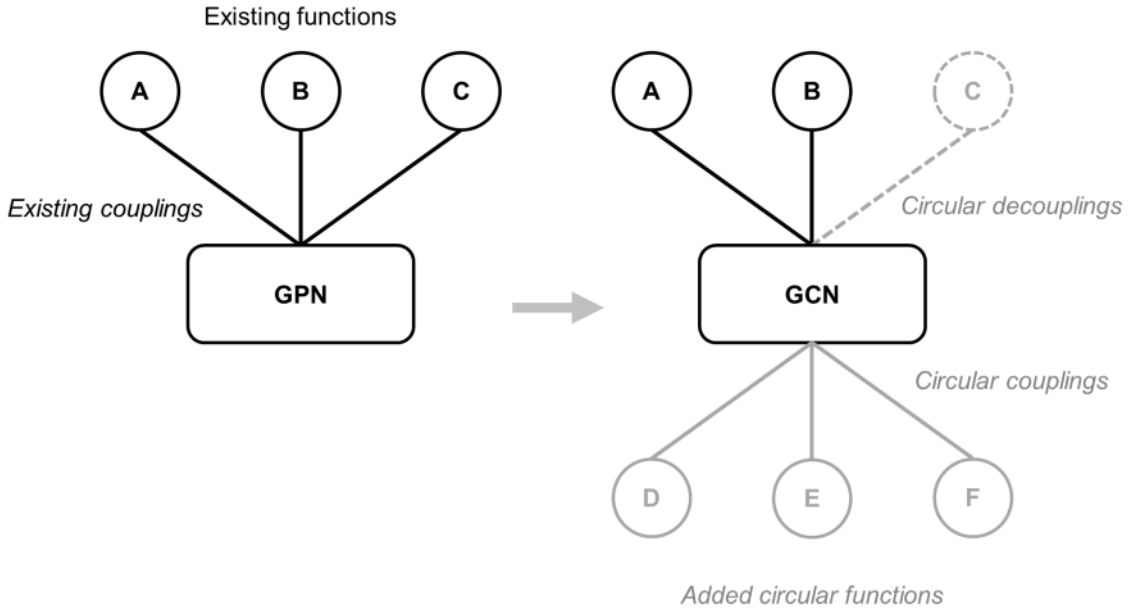


*Figure 1: Schematic depiction of the change from GPNs to GCNs (Global Circular Networks) involving the dynamic mechanism of circular (de)couplings.*

But where and how can these circular couplings be observed? We argue that these couplings are visible in processes by which new functions are added to and integrated into existing GPNs or in the formation of emergent and novel GCNs. Thereby, we consider the CE functions to encompass what is discussed in the literature as different R's (Reike et al., 2018). Depending on the form and scale of GCNs, this may therefore relate to a set of different additional functions, correspondingly involving multiple couplings (see Figure 1). Table 1 outlines the basic functions of GPNs and the CE to be considered in the formation of GCNs and their resource flows. While we only sketch these functions here to make visible the difference between classical GPNs and GCNs, section 3.2 will provide brief empirical illustrations of circular couplings.

[4] See online: https://www.ellenmacarthurfoundation.org/circular-examples/groupe-renault, 2024-12-19

*Table 1: Functions of the global and CE in GPNs (based on and adapted from Coe & Yeung, 2015; Reike et al., 2018)*

| | **Purpose** | **Definition** | **Resource flows** |
|---|---|---|---|
| Global economy | Knowledge generation and organization | All activities of research and development, the coordination of firms, networks, and production in GPNs | Direct energy usage, embedded energy in infrastructure (including digital), and energy for mobility; raw materials e.g., prototyping, equipment, and infrastructure |
| | Processing & manufacturing | All activities that encompass the production of goods, manufacturing, processing of material, and distribution of manufactured goods in GPNs | Direct energy usage (heat, steam), for automation and digital technologies, logistics; intermediate goods, consumables in manufacturing, production waste, and logistics materials (see Acquaye et al., 2017) |
| | Raw material sourcing | All activities related to the sourcing of materials and minerals relevant to manufacturing and processing | Energy for extraction and pre-processing; primary materials like minerals, and ores; byproducts and waste; water; consumables, transport (see Acquaye et al., 2017) |
| Circular economy | Material transformation<br>Input: waste and energy | Activities related to<br>*Remining* of materials from waste<br>*Recovery* of energy and materials from waste<br>*Recycling* of waste and materials<br>*Repurposing* of used goods for other products and services | Tendency for large loop; excavation energy, transport and processing – e.g., separation; operational energy; recovered materials, byproducts, residues; repurposed products (see Danthurebandara et al., 2015) |
| | Upgrade/ adaptation<br>Input: product and product parts | Activities related to<br>*Remanufacture* of used components in other goods and services<br>*Refurbishing* of used goods through integration of new parts<br>*Repair* of used products through replacing destroyed parts | Medium loops; energy for disassembly, diagnostics and inspection, reprocessing and maintenance, assembly and transport (decentralized); Recovered components, replacement materials, spare parts, and product outputs (see Lechner & Reimann, 2015) |
| | Product (re)use<br>Input: product and product parts | Activities related to<br>*Reselling/Reusing* products through 2nd hand<br>*Reducing* materials in production (by design) as well as initial product consumption and sales<br>*Refusing* initial product consumption and production | Small/medium loops; energy for collection and inspection, transport, and retail; materials for packaging and redistribution (e.g., Nørup et al., 2019). |

## 3.2 The geography of circular couplings

In this section, we synthesize the conceptual discussion so far by elaborating on the nexus of actors, functions, and resources in which actors engage in circular (de)couplings. We use the term nexus to signal that the shift to circular couplings involves an expansion of the state-firm nexus that is traditionally the focus of GPN literature. Our model has three dimensions (Figure

2), which we have elaborated on in previous sections and expand on below by linking to related literature.

First, we incorporate a broader set of functions which include material transformation, upgrade or adaptation, and product (re)use, in addition to the canonical functions typically emphasized when studying global production (see Table 1). Economic geography research has a long history of studying functional dynamics in local and multi-scalar systems of innovation and production (see Asheim et al., 2016; Binz et al., 2016). Current frameworks typically distinguish between processes that lead to the build-up of new structures for resource provision, the realignment of existing structures, and the dismantling of structures that are no longer necessary to provide key industries with resources (Miörner & Trippl, 2019; Trippl et al., 2020). We expect a shift towards more circular production patterns to lead to substantial reconfigurations of regional functional dynamics, as regional actors seek to exploit the opportunities and respond to the pressures, that emerge when directionality changes in GPNs or emerging GCNs. It has also been demonstrated that context conditions (geographical- or field-/sector-related) affect how different actors value resources and visions about their future use (Jeannerat, 2024; Miörner, 2022).

Second, in terms of actors, the model includes a new set of non-firm actors, such as consumers, as well as expands on the role of firms and states in facilitating and coordinating resource flows, following insights into the CE literature. Actors' strategies are shaped by geographical- and sectoral context conditions, and in turn shape circular (de)couplings in non-negligible ways. For example, regional actors may respond to external impetus created by actors elsewhere by utilizing existing regional production- and innovation capabilities (structural couplings). Circular (de)couplings may also be driven inside-out by actors who push a circular agenda strategically in existing GPNs or novel GCNs (organic couplings) or actively engage in regional reconfiguration processes to substantially alter or create functions for the CE (functional couplings). Finally, the role of consumers as active parties in value chains demands firms to establish new relationships based on new business models, such as rental or product-service system designs (functional couplings). Following the literature on strategic agency in economic geography, we expect the types of agency to differ depending on the type of actor and the structural opportunities or challenges they are faced with (Grillitsch & Sotarauta, 2020).

Third, in terms of resources and resource flows, the scope is furthermore expanded from a focus on immaterial flows in GPN studies (i.e., knowledge, value) to include material resource flows such as residual flows, spare parts, and (raw) material inputs. Table 1 indicates how circular (de)couplings relate to different types of resource loops, ranging from large (the circulation of resources in relationally and geographically distant networks), and medium to small (involving direct contacts and geographical proximity between users and (re)producers of resources) loops. The relational dimension of resource loops refers to the degree of functional integration between actors in different parts of the value chain. Through circular (de)couplings, we may see an increasing integration in terms of how suppliers of materials adapt their value-creating activities differently to consumers (e.g., by functional upgrading in a circular sense, moving along the spectrum of R's), but this is not a necessary condition for a shift towards a more circular global economy. It can also be the case that suppliers reorient their activities and produce circular resources that can directly substitute linear ones in existing large resource loops.

As a result of dynamics in these three dimensions, we expect to see more geographically diverse and complex resource flows in production networks, and more variegated roles of regions in these. When considering functions in the CE, regions play a key role in terms of valuing resources that flow into the region (through existing couplings), the processes through which

they are transformed, upgraded/adapted, or (re)used in production and consumption in the region, and facilitating resource flows to production- and consumption activities in other regions.

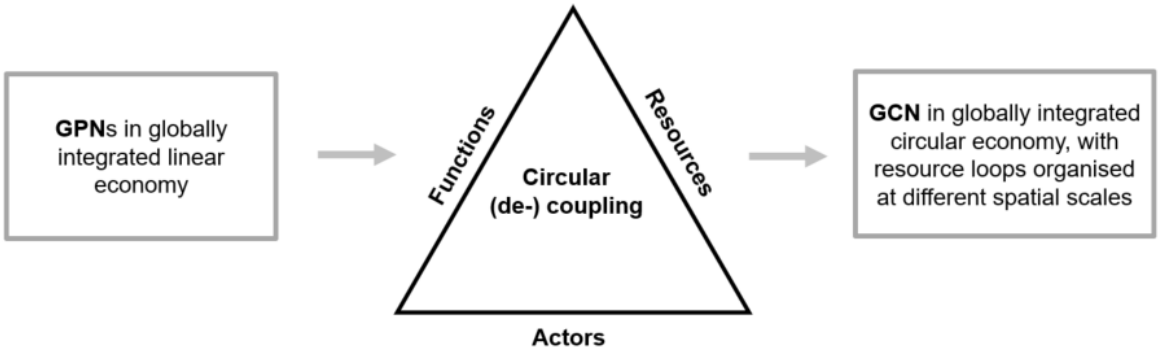


***Figure 2:*** *The geography of circular (de)couplings and the actor-resources-functions nexus.*

In the following, we illustrate the different characteristics of each dimension, based on four examples of circular (de)couplings in the global economy (see Table 2). It is possible to imagine many more potential combinations, and the conceptual and empirical relevance of the ones outlined here are subject to future studies, representing a long-term research agenda. Nevertheless, these illustrations show the applicability of our model to analyze the emerging phenomena of a globally integrated CE.

**(1) Design and material transformation by lead firm**

This type of (de)coupling starts from the notion that some resources, crucial to existing GPNs, are becoming increasingly scarce. In combination with policies that require producers to take responsibility for discarded products, this pushes firms to pay attention to what happens to their product after consumption and how to take care of, for example, metals and other materials used in their production processes. For example, the End-of-Life Vehicle Directive in the European Union requires that new vehicles be recyclable or reusable to 95% of their weight. Two possible dynamics are currently observable. First, most European countries host authorized treatment facilities that extract resources from used vehicles, supporting manufacturers to fulfill the directive (organic coupling). Used vehicles are dismantled, and materials are shredded and sorted for basic recycling (material transformation: remining and recycling). The technological capabilities required to recycle the material are low, meaning that in many regions the necessary regional functions for production can easily be built up (creating new regional functions). Due to the legal status of the directive, the valuation of the resulting materials is not dependent on local markets and exploited by entrepreneurs located in each national vehicle market. This type of coupling is characterized by large resource loops in which the authorized treatment facilities and the end-user are geographically disconnected. Shredded metals are sold on secondary markets for recycled metals and may end up in a range of industries other than vehicle manufacturing. As such, this type of circular coupling may link different manufacturing industries through overlapping resource loops.

Second, this can lead to changes in the design or production process, aimed at enabling loops in later stages (e.g., recycling). Changing the design of a component or process within an existing GPN may include various functional (de)couplings as some suppliers become redundant and hence decoupled whereas others might strengthen their position in the GPN. An example is megacasting within the automotive industry where larger and more complex components are produced. Fewer components and a lower mix of materials enable recycling

during the downscaling phase. These new couplings are triggered by normative pressure on lead firms and directives such as the EU's End-of-Life Vehicle Directive. The changing function creates new opportunities for actors within the GPN, who can follow the technological development. The spatial dynamics will reflect the ones in the existing production networks with reduced actors involved.

**(2) Product service systems with new local actors**

There are several initiatives and concepts related to the extended use of products, such as rental models or Product Service Systems (PSS), which enable small loops. By focusing on the maintenance, refurbishment, or repair of products (adaptation), PSS reduces the need for new materials and promotes sustainable material cycles by making better use of existing products. Rather than producing more goods, PSS promotes designs that are durable and repairable. For example, Tsui et al. (2023) report on 'circular construction hubs', i.e. specific locations where secondary resources are collected, stored, and redistributed for renovation or new construction projects. They report that the localization of hubs must be within a radius of 30-50 km in urban areas, forming small resource loops. The development of these circular hubs requires the establishment of specialized businesses that provide functions such as repair and refurbishment of building materials (organic coupling). Subscription and rental alternatives in consumer goods with temporal usage (e.g., children's equipment, tools, etc.) are another example. Reuse is possible for 8-12 user cycles with cleaning and minor refurbishment as well as quality and safety checks being done between the cycles. While most newly manufactured consumer products are produced in Asia, the new processes of refurbishment and quality/safety checks need to be performed closer to the consumer to minimize transportation and last-mile logistics (small resource loops). New remanufacturing actors are emerging that provide different specialized functions and components to garments (organic coupling).

**(3) Product adaptation in an existing GPN**

Lead firms in existing production networks are put under normative pressure (from policymakers or consumers) to shift to more sustainable modes of production. By refurbishing or repairing (product upgrade) they aim at reducing waste, thereby responding to emerging market niches where there is a demand for refurbished parts of end-products. This type of strategic coupling is driven by lead firms who typically utilize their existing production capabilities in regions that are already strongly embedded in their GPNs. Volvo Trucks in Sweden e.g., offers 'circular parts', which are essentially reconditioned parts that have been removed by Volvo Trucks' service providers at the end of their (original) life. They are refurbished in Volvo Trucks' facilities (thereby relying on existing regional functions for vehicle production) and delivered with the same 2-year warranty as new products. This represents a medium loop with close relationships between Volvo Trucks and service providers but where consumption takes place in standardized and often geographically distant markets. The resource loops are often completely contained within the original GPN – both waste and the resources resulting from product upgrading never leave the GPN that is controlled by the lead firm. This means that spatial dynamics reflect those of existing production networks. Regional context conditions may nevertheless have some importance in valuing the refurbished end-product, in terms of assigning a premium (or not) on circular parts.

**(4) Waste-to-value by lead firm**

In this example, lead firms couple with local firms (e.g., startups) to align their production model with their circular strategies. By material transformation (e.g., recycling, recovery) of waste resources from existing production processes they aim at reducing waste, creating value, and coupling into emergent networks. This type of functional coupling is driven by lead firms

coupling with novel regionally available capabilities (e.g., recycling or recovery facilities). For example, the dairy company ARLA partners with the startup ENORM for the recovery of energy from waste in their production facilities (insect cultivation on dairy waste). This process is characterized by the provision of novel regional functions by local firms and relates to large resource loops. The resource loops connect the existing GPN with novel production networks, thereby forming GCNs. The spatial dynamics depend on the shape of these networks that are formed around the material transformation of waste. These can principally be oriented along different scales, yet the couplings can also regionally take place due to the regional availability of waste streams and logistical constraints.

*Table 2: Illustrative examples of the geography of circular couplings*

| | **Functional dynamics** | **Actors and coupling** | **Resources** | **Geography** |
|---|---|---|---|---|
| **(1) Design and material transformation by lead firm** | Creating new regional functions | State policy<br>Organic couplings | Large resource loops overlapping different industries without functional integration | Spatial dynamics reflecting those of existing production networks |
| | | State policy & lead firms<br>Functional couplings | Large resource loops create GCNs | |
| **(2) Product service systems with new local actors** | Creating new regional functions | Specialized actors<br>Organic couplings | Medium/small resource loops | Regional contexts important for valuing resources |
| **(3) Product adaptation in an existing production network** | Realignment of existing regional functions | Lead firm<br>Strategic couplings | Medium resource loops<br>Resource loops contained within existing GPNs | Regional context matter for valuing refurbished products<br>Spatial dynamics reflecting those of existing production networks |
| **(4) Waste-to-value by lead firm** | Creating new regional functions | Lead firm<br>Functional coupling | Large resource loop<br>Resource loops connect different GPNs | Regional context somewhat important for downcycling<br>Regionalization of spatial dynamics |

# 4 Conclusion

Based on the argument that we need to consider the existing global architecture of the economy as a point of departure for circular changes, we have conceptualized the globally integrated CE through the notion of GCNs (global circular networks). This adds a new, previously neglected stratum to the growing geographical literature on the CE (e.g., Bourdin & Torre, 2024; Davies et al., 2024) and contributes with a concept of directional change to the classical geographical study of economic processes of globalization (e.g., Coe et al., 2004; Dicken, 2015; Henderson et al., 2002; Yeung & Coe, 2014). We have outlined how changes from GPNs to GCNs can be conceptualized through the mechanism of circular (de)couplings. This is understood through

the addition of circular functions and the substitution of existing functions in GPNs. To understand these processes and their spatial implications, we have outlined the actors-functions-resources nexus, where economic relationships can be reconfigured and transformed from linear GPNs to GCNs. We have illustrated this conceptual approach with possible couplings identified in existing literature. Our illustrations present a variety of possibilities for how these circular couplings take shape: this includes changes originating from lead firms in existing GPNs, developments originating from local firms in existing GPNs, (lead) firms creating new GCNs, and developments by actors outside existing GPNs.

Our framework allows for the study of the multi-scalar architecture of the CE, considering the variegated outcomes across space. The geography of these aspects, and how global or regional/local GCNs are shaped, affects the sustainability of these networks. As research on international waste trade in the context of the CE shows, this concerns not only transport emissions but also negative social impacts in distant places (Thapa et al., 2024; Thapa et al., 2022). Furthermore, our framework allows us to visualize the changes in GPNs towards circularity and how they involve different actors, including lead firms, regional actors, policy, etc. We argue that with the conceptual vocabulary provided in this paper, we can now not only map these actors but also study the power relations and shifts in these subsequent circular developments. Building on the notion of resources (material and energy), which has so far been neglected in GPN work, it also allows us to outline new links that emerge in the operationalization of CE between existing GPNs. These links, and how they encompass more than just economic value, need to be further explored. In particular, this may also be a first attempt to bridge what has been discussed as 'global destruction networks' (Bryson et al., 2024; Herod et al., 2013) with the work of GPNs in considering the whole life cycle of products. This suggests, for example, the importance of 'following the things' in emerging GCNs to better understand the intersections of different GPNs. We emphasize that these intersections should be further unpacked in terms of actors, governance, and geography.

Another implication concerns the role of lead firms in circular change. Our research underscores their critical role in driving change. Not only because these actors control supply chains, but also because they must be held accountable for the limited and incremental steps towards circularity they are currently taking. Our illustrations show that lead firms focus primarily on recycling, rather than reuse or refuse. The selective use of R's is a well-known problem in the operationalization of the CE (Corvellec et al., 2021; Korhonen et al., 2018) and risks failing to account for reduced material throughput and reduced use of virgin materials. This calls for policy and behavioral changes to steer these firms towards more sustainable resource flows and reduced use of virgin materials. In particular, also because these firms may tend to 'dissociate' (Ibert et al., 2019) from certain negative aspects of their production in order to create and capture economic value, instead of implementing real changes oriented towards circular value creation, potentially leading to a more far-reaching (spatial) reconfiguration of their GPN. In this sense, it is not enough to set up a flagship factory, but to rethink and reconfigure the existing architecture and geography of GPNs in order to leverage circular development.

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