Towards a Network Approach: Production Environments of Digital Innovation in the Global South and their Function in Social Transformation Processes

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List of publications

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1) Schmitt, D. (2019). Production Environments of Digital Innovations: A Scalar Perspective on Cultural Legitimacy in Zambian Coding Networks. *Perspectives on Global Development and Technology*, *18*(5-6), 527-552. DOI: https://doi.org/10.1163/15691497-12341531

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The published version is reproduced in Chapter 4.2 of the thesis.

III. The Outline

The concept of transformation is everywhere and is increasingly becoming a core element of scientific and social discussions in times of major crises. Whether geopolitical situations, economic uncertainty, disruptive technological innovation, or the climate crisis, the fundamental mechanisms of societies seem to be shaken worldwide, and profound social change is being communicated as a necessity from more and more quarters. Transformation in this sense is understood as a radical systemic change in value and belief systems as well as behavioural patterns, behaviour in social environments, and multi-level governance and management schemes (Temper et al. 2018) and can accordingly be understood as societal transformation. In other words, it is not about targeted, small-scale adaptation, but about truly upending a system that does not seem ready to deal with the social challenges of today and the future. This is vividly illustrated by Feola's (2015) differentiation of *Societal Transformation* from *Transformational Adaptation*. The former refers to the redesign of modern societies, as opposed to the reactive change in spatially and functionally delimited systems of the latter.

The radical nature of systemic change is rarely without conflict. Where deep-seated structures are changed, people and institutions revolt and either question the goal of the transformation or open discussions about "the ways" to reach the target and who or what can and should face trade-offs. In practice, there therefore is no one-sided fixed belief in the one-dimensional positive power of transformation, but rather a diverse reflection on what societal transformation means in the thematic situations and environments for all actors concerned (Troeger 2016). The IPCC (2018: 922) emphasizes an appeal for caution in the same tenor: "as a fundamental change in a system transformation may involve changes in actors' objectives and associated values […]. [T]he greater level of investment and/or shift in fundamental values and expectations required for transformational change may create greater resistance". Accordingly, social change must always be viewed ambiguously. On the one hand, there are the results of the change processes intended by the involved and powerful actors; on the other hand, there are the costs, side effects, consciously accepted conflicts and, last but not least, the unpredictability associated with the transformation.

Transformations are multi-layered, transformations are protracted, and transformation processes interact with each other. A complexity that makes it necessary to differentiate and specialise in the course of a research project. This dissertation is therefore concerned with two perspectives on transformation. On the one hand, the digital transformation, which replaces analogue processes, reveals new facets of potentials across societal structures, and brings disruptions to all areas of life. On the other hand, the aforementioned social component of transformation, which considers not only technological change, but also change on societal level in particular. With the integration of digital technologies into the everyday lives of more and more people worldwide and the increasing scope or potential of technologies to redefine, expand, or even manipulate social functions, the need to understand the interaction between technical and social systems is obvious. In practice, this for example means: what interpersonal and social changes accompany new digital communication channels? How does interaction with digital tools and their content change value systems, and how can intentional benefits of technology be differentiated from unintentional side effects? And above all: what drives

technological infused transformation processes and what influences steer it into a certain direction?

The impact of digital technologies on social transformation processes becomes even more relevant when considering the Global South, a socioeconomic context defined by its diversity (Francis et al. 2020) and place of research for this work. The duality of traditional and indigenous structures on the one hand, and the ever-increasing integration of digitization and changing economic practices and modern governmental and civil society frameworks on the other, illustrate the complex tension created by a globalized world and within which the research of this thesis is situated. The empirical data in this dissertation are therefore drawn from a variety of African countries, with Zambia being the focus. This work is thus also a balancing act of globalization between the new digital technologies originating predominantly in the West and Asia and their impact on the socio-cultural diversity of a continent that is currently undergoing very rapid change.

Ongoing research on societal transformation that is influenced by technological systems illuminates some explicit foci on three structural dispositions:

1) Empirical research on historical or ongoing transformation processes that analyses impacts or changes occurring due to the implementation of technological innovations (e.g. Ernst et al 2016, Osunmuyiwa et al 2018, Roberts & Geels 2019),

2) conceptual work on socio-technical transformation and system dynamics (e.g. Geels 2011, Geels 2020) and

3) Policy or economic driven analysis and recommendations for targeted (and therefore desired) socio-technical transformation processes (e.g. Anderson et al 2019).

All these studies have the same research object, namely technology in a specific socially dynamic environment. And they try to answer how social actors interact with the introduced technology and what effects arise from its application. This dissertation argues in favour of a fourth perspective, which in the contextual problematization of ongoing socio-technical transformation processes (especially in the Global South) has so far been neglected. This perspective is built on two major arguments: First, by putting a focus on

the production rather than the implementation environments, dynamics between social and technical structures in the earliest stages of technical developments shift to the centre of attention, complementing existing transformation research on implementation and impact stages. Second, by analysing technological innovation as a result of network activities, the research focus shifts from the finished technology itself and its implementation and adoption to the influences behind its conceptualization, design and production. Accordingly, transformation processes are understood as relational processes, which only acquire meaning through the connections between actors and interactions with the resulting technology.

Technological innovation' and the term 'digital innovation', which is used in context of the examined case studies are used synonymously in this paper. It is therefore important to first define this research object clearly. As Lyytinen et al. (2020: 279) state, there is no "common vocabulary or generic framework of digital innovation" due to different focuses of different scientific disciplines. For this thesis, I define digital innovation according to Hund et al. (2021) as an interplay of digital objects and their intended creation of value. Digital innovation in this thesis is therefore ultimately about software including its fulfilment of functions. This includes, for example, smartphone apps, websites, or backend-oriented digital architectures such as databases, APIs, or algorithms for analysis and evaluation purposes in combination with the service provided to the user group.

As highlighted by Leonardi (2012), technology should not be conceptualized as a fair-minded tool that is decoupled from its environment. Instead, its embeddedness in institutional and social structures influences its effects once implemented. This approach naturally applies to the implementation as well as to the production environment. But when it comes to understanding digital technologies in Africa, only a few studies have shown technology's links to its production environment (e.g. Friederici 2016, Quinones & Heeks 2020). Instead, the focus still lies on either the technology itself, its effects on the implementation site or both. At the same time, there is a large consensus that technology is most effective when developed by actors who are locally rooted in the same context as its intended use (Matuschewski 2006, McQuail 2007, Unwin 2017,). This line of thought originated from the realization that "technology is not neutral" (Polgar 2011: 17) and

carries inherent characteristics, which derive from the sociality of involved stakeholders in its production phase. In this regard, both social structures and technological properties are limited in understanding societal transformation processes when studied separately. The interactions between social and technical components of transformation instead create systematic structures with the purpose of fulfilling specific societal functions that can only be achieved with the support of technology (Geels 2004). These structures are famously conceptualized as socio-technical systems, which are defined "as the linkages between elements necessary to fulfil societal functions" (Geels 2004: 900). Considering social and technical components as different sides of the same medal, their contextual fit is therefore rightfully put forward when trying to understand transformational potential and processes of new technological innovations. At the same time, there is a lack of empirical work for the Global South that explicitly targets the formation phase of technology, while already completed technologies are receiving much higher attention rates. And although the importance of a technology's context is eminently highlighted, so far scholars mainly focus on a binary status that evaluates in either domestic or foreign categories (Quinones & Heeks 2020), an argument that the empirical output of this dissertation aims to refute. The first argument behind this dissertation's empirical focus is therefore intricately linked to the question of where technological innovations come from and what their production environments in the Global South look like. By putting a focus on production rather than implementation environments, the socio-technical system integration of a technology and its developers can therefore be analysed from a new angle that complements existing transformation research. Getting a different understanding of why, how and by whom technological innovations are shaped can hence be considered as the first major goal of this dissertation.

Analysing technological innovation as a result of network activities and therefore shifting to the *influences* behind its conceptualization can be seen as the second major research focus of this dissertation. As many scholars and practitioners pointed out, information and communication technologies in the Global South rarely succeed in achieving their initial goal (Avgerou 2008, 2010; Avgerou and McGrath 2005; Hosman and Fife 2008; Walsham 2012). Lin et al (2015: 698) base this on "a lack of understanding of different underlying perspectives and context diversities" (Lin et al 2015: 698). Some scholars even

go as far as building hierarchical ladder models to visualize the participation and intensity of engagement with digital technologies (Heeks 2018) or emphasize bottom-up versus top-down approaches to unfold technology's potential and explain why it is often not reaching its targeted goals (Lund & Sutinen 2010). This dissertation argues that the firm differentiation in contextual and therefore local and outside technological innovation is not reasonable due to the diverse production environments behind new technologies that cannot be hierarchically ordered in static categories. Instead, by adopting concepts such as the Multi-Level-Perspective and Niches from innovation science, which have a rich tradition in understanding how technical change processes come to place and interact with social structures, in this dissertation innovation is conceptualized as a result of network activities that show diverse layers of engagement and influences among all involved social agents, institutional structures and knowledge levels (Geels 2002, Geels 2004). In other words, technological innovation does not happen in isolated settings that can be defined as local, contextual or bottom-up. They rather evolve from a network of different actors and institutions that shape and develop it over time. The objective of research is therefore not to evaluate outcomes or understand specific impacts of technology on social structures but instead this dissertation tries to analyse the drivers behind technological innovation that undoubtedly possesses transformative potential.

Finally, this work is situated in the field of tension between two academic disciplines that have so far been in rather marginal contact with each other. On the one hand, the established development studies, which sees transformation as a core element of development progress and has historically gone through different cycles: from overbearing "expert transformation" to participatory and decolonizing views on the improvement of living conditions. The other is the more recent discipline of sustainable transformation studies, which analyses the interdependencies of technology and society in a structured way in the wake of the climate crisis and works toward transformative changes to combat climate change. Both disciplines have their focus, strengths, and perhaps weaknesses in this regard. Therefore, in this dissertation the theoretical repertoire of transformation studies has been particularly strong, while the inputs around power, influence, unintended side-effects, and more generally the question of justice come from development studies. Last but not least, the network perspective and the own background

invites to work with methods of computational social science, which are rather unusual for the field. Thus, the empirical research as well as the theoretical framework of the thesis reflects the core of this dissertation: to interdisciplinary analyse the phenomena around social transformation in the Global South, which are induced by digital technologies.

To address these above-mentioned research trends and arguments, the next chapter follows the discussion on societal transformation and technology innovation from a theoretical point of view and forms the first part of this dissertation. It starts with a coarse analysis of the meaning of transformation in the context of social structures and moves forward to more refined and specific theories concerning technology, its influences, drivers and transformative potential in the Global South. This theory chapter ultimately runs centrally towards the Multi-Level Perspective and here in particular the role of the niche concept in the innovation process of new technology. After discussing the Methodology, the empirical part of this dissertation is then subdivided into three articles, all of which are incorporated into the core arguments elaborated in the theory chapter.

Article one focuses on a case study of Zambian coding networks and the cultural legitimacy of digital innovation. Article two uses computational social science methods to analyse three development environments in the form of coding networks from Zambia, Ghana, and Uganda and show how they are internally structured to interrelate The third article then connects the MLP at a conceptual level with exemplary findings from the ICT4D studies to ultimately enable a more appropriate application of this framework in the Global South.

1. Theoretical Debates and Conceptual Linkages

The following theory-oriented chapter first introduces the various conceptual branches in terms of processes and outcomes of transformation to subsequently relate these with the overarching topic of production environments of digital innovations in the Global South. Current scholarly debates are being specified around transformation, the perspectives of sustainability, and technological innovation in terms of fields of production are discussed. Further it discusses the connections between technical tools and social structures are

discussed and introduces the diverse fields of information and communication technology in a development context and its relation to transformation studies. The chapter closes by combining the previously established connection between a socio-technical perspective a geographical dimension, ultimately highlighting the value of geographical network science and relational space and scale conceptualizations.

1.1 Dimensions and typologies of transformation: Intertwined views on socio-technological transformation

In recent years, the scholarly use of the term 'societal transformation' has been on a steady rise. In particular, due to an increased focus on social science research focusing on global environmental change and the growing diffusion of technology in everyday life, concepts of social change are gaining considerable momentum. While a variety of scholars embed the term in their own field of study and sow the seeds of an interdisciplinary debate, the actual conceptual framework with distinct definitions varies from author to author and complicates a standardized linguistic usage (cf. Brand 2016). To avoid a mere metaphorical utilization of the term, as argued by both Feola (2015) and Brand (2016), a firm conceptual foundation must be a fundamental part of research on transforming societies to elevate the discussion above buzzwords, the use of which would eventually dilute progressive debates.

The following theory-driven perspectives on transformation give a summarized overview of recent debates. They serve as the foundation on which the research design is built. On this basis, this argumentative step seeks to specify the theoretical foundations to make them available for empirical and realistic research. The last section combines the theoretical and the empirical approach and elaborates on its relevance for the overarching research structure for this dissertation.

There is a wide consensus that "*transformation* is a process of structural change, i.e. a change of fundamental patterns, elements and interrelations in the system" and proceeds "via a combination of endogenous and exogenous process, involving both emergent, inadvertent, unintended consequences and intended, deliberate ones" (Feola 2015: 382).

What distinguishes transformation from other forms of change is its systematic nature that can be characterized as nonlinear, sustained or deep (Fazey et al., 2018; Feola, 2015; Linnér and Wibeck, 2019). The IPCC (2018: 70) report also divides changes into two strands and writes that (adaptational) change "can be incremental, or transformational, meaning fundamental attributes of the system are changed" Nevertheless, the questions of the subjective interpretation of 'fundamental' change and how this interpretation is used in academia and policy creation remain blurry.

When it comes to *societies*, the analysis of social structures itself has a long tradition in sociological theory under the premise of the inherent limits of human control. Here, societies are differentiated in various subsystems, e.g. production and consumption patterns, legal concepts and norms, governance organization, cultural practices or belief systems that enable investigation through a defined unit of measurement (Costa & Murphy 2015) Identifying individual and collective behaviour patterns or institutions therefore help in making the composition of a society more accessible for empirical evaluation. Both the definition of transformation and the analysis of society follow a clear conceptual pathway, however if combined with the notion of societal transformation, there is some contestation on whether a specific outcome is an inevitable feature or just one of many given values of transformation (Feola 2015). In other words: when can changes in social subsystems be characterized as (societal) transformation and on which organizational principle is transformation eventually measured? To differentiate between various meanings and clarify the conceptual framework of societal transformation, Feola (2015) distinguishes the *emergent-transformation* perspective from a *problem-based* one and opens two angles on approaching future research on transforming societies.

From an *emergent-transformation* perspective, the spotlight lies on a descriptive-analytical approach. It is built around identifying patterns that are considered definitive of transformation, but there is no attachment of value to a specific configuration of them. This conceptual framework considers the direction of change without conditioning the outcome to a certain goal. Thus, with focus on distinct pathways, the outcome of change does not determine whether it is transformational or not (compare Grin et al. 2010, Shove et al 2012, Feola 2015). Emergent transformation "calls for descriptive approaches to the

issue of transformation, and leaves open ground for the understanding of change as a result of inadvertent or deliberate processes." (Feola 2015: 384). Empirical inquiries then have the task of identifying definitive patterns and units (subsystems) and their interdependencies to understand the complexity of human interaction with their social and ecological environment. The transformation is only recognized after its definite completion in relation to previous conditions that, in connection to the changes, can then be recognized as outworn.

The second perspective proposed by Feola (2015) calls for a prescriptive conceptualization of societal transformation. In contradiction to the emergent approach, it specifically includes predetermined directions of change. These directions are always orientated on "substantial and widely distributed benefits to both society and ecosystems" (Marshall et al. 2012: 2), adaptation and/or positive impact in stakeholder's agency. The concept of transformation can then accurately be measured with the performance of change in connection to a particular set of normative values (e.g. road towards sustainability). This way, social science research has a strong "strategic and operational approach to the issue of change" (Feola 2015: 384) and places itself in a more active role in the process of ongoing change. This prescriptive and solution-orientated approach therefore places explicit emphasis on the deliberate development of transformation and follows a predetermined idea of desirable outcomes.

Based on Feola's (2015) distinctions, two major criteria were essential for the development of further theoretical and empirical approaches. First, there are key drivers (both individual and institutional) behind technological innovations that impact and influence societal transformation processes. Second, these key drivers function under various agendas that deliberately steer discourses around technological innovations towards a certain normative direction and therefore shape technology that is both newly innovated and implemented.

The objective of this dissertation is to understand the drivers behind societal transformation which are facilitated through technology. These outcomes are then further linked with questioning the perspective of sustainability. It is correspondingly essential to understand the deliberate direction of transformation efforts. While the chosen

theoretical frameworks, approaches and models therefore derive from a prescriptive perspective on transformation (sustainability transformation), the empirical research and data analysis is not focused or limited to evaluating positive or negative aspects that foster or hinder transformation. Instead, this research aims to add insights into drivers of transformation in the specific prescriptive setting of technological innovation networks and therefore utilizes perspectives from this already well-established scientific branch to better understand the influence of technology on societal transformation from a path independent and open perspective.

Going beyond the debate on these definitional aspects of societal transformation, the actual empirical research on change within a society can likewise be approached from various angles. When advancing from a prescriptive, yet explorative viewpoint, empirical inquiries on basis of social subsystems can construe a comprehension of ongoing change. But as argued by Schneidewind & Augenstein (2016), instead of just documenting this transformational process, a deeper analysis should focus on the major drivers behind change to improve our understanding of transformations and uncover probable determining factors. Out of this strategic focus on drivers, Schneidewind & Augenstein (2016: 88) deduce "three schools of transformation thinking": The idealist school, the institutional school and the technological innovation school.

With the idealist school arguing that *ideas* are the focal point of every concrete aspect of human experience, ideas per definition play a central role in societal transformation as well. In this line of thought, ideas are not understood as individual conceptions, but rather as collective, intersubjective ones that are "embodied in symbols, discourses and institutions" (Legro 2000: 420). Therefore, to "explain and to analyze [societal] transformation, we have to understand basic ideas (cultural values, dominant dogmas and world views) and how they impact societies" Schneidewind & Augenstein (2016: 89). The deductive reasoning then points out *ideas* as the most relevant determining factor of societal transformation and therefore as the linchpin for research.

The institutional school on the other hand puts emphasis on the role of institutions in determining the process of changing societies and follows a structural approach. With institutions serving as guideline for individual behaviour, every action is automatically

channelled through institutions, awarding the action with the deepest root of power. The selection of acceptable, possible and legitimate activities creates stability within a society and shapes all individual and collective behaviours (Schneidewind & Augenstein 2016).

The technological school picks up the idealist and institutional concepts but adjusts their

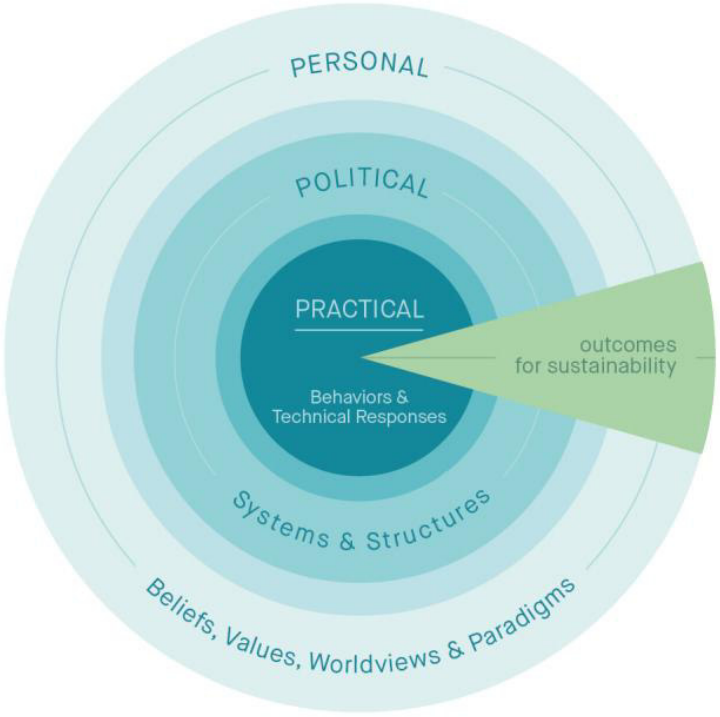

Figure 1 The three spheres of transformation (O'BRIEN & SYGNA 2013)

value and capability for convertibility. It assumes that established basic norms and values are uncontested in their institutional framework and cannot or should not be changed (e.g. democracy or human rights). Thus, societal change is seen through the lens of innovation and technological advancement (Ingelhart & Welzel 2009). These three schools should not be reflected upon as opponents or isolated from each other, but instead they assign the dominant force behind transformation to different central aspects of their own core understanding of society (Schneidewind & Augenstein 2016). They thus provide relevant entry theorization for both the to be analysed subsystems and their interdependencies as well as the positionality of the researcher in social science research resulting in a suitable framework for further analysis.

To structure these basic principles, perspectives and drivers in a meaningful fashion and to propose a framework for research on the different subsystems and their impact on transformational processes, O'Brien & Sygna (2013) introduce three spheres of transformation: *practical, political and personal*.

Although the spheres are visualized as flat (see figure 1), they are embedded within each other and at the same time follow a pertinent order. While the practical sphere represents the targets and goals of a deliberate action towards transformation, the political sphere determines the enabling or disabling conditions that regulate the establishment or denial of the process. Therefore, the practical heavily correlates with the political sphere. The personal sphere "captures individual and collective views of systems and solutions" (O'Brien & Sygna 2013: 19), hence on a similar note highly interacts with both the political and the personal sphere. As a result, the spheres should not be interpreted as a static model with clearly defined borders, but instead as permeable distinctions with interconnected relations.

The practical sphere is what most current research is attracted to right now and which is captured by Schatzki's (2002) 'ontology of site' or 'the site of the social'. The 'technical' changes (organizational, technological, and behavioural changes in social structures) can be observed and analysed here. Accordingly, O'Brien & Sygna (2013: 19) refer to it as the "outcome" sphere. At the same time, focusing on practical modifications is not sufficient enough to understand the process of societal transformation as it disregards deeper social structures. In line with the institutional school of thought, the political sphere therefore adds the dimension of "constraints and possibilities under which practical transformations take place" (O'Brien & Sygna 2013: 20). Under the premise that cultural, social, legal, political and economic structures in society influence changes in the practical sphere, these systems frame and shape every transformation process. But with the same argument of interrelations, the political sphere is not independent from other influences. Individual and collective worldviews, norms, knowledges and values structure the understanding of institutions and generate different priorities and interactions with the

political and practical sphere. The personal sphere therefore represents the outer part that influences the core understanding of said institutions and practices.

The conceptualization of emergent and problem-based perspectives, of different schools of transformational thinking and of different analytical spheres of accessing transformation processes highlight the complex topic of societal transformation from different scientific angles. As exemplified above, societal transformation is such an extensive theoretical foundation with entanglements in various fields of studies that in order to deliver stringent, accurate, relevant and interdisciplinary research the derived at theoretical foundations of this dissertation are based on the following three pillars:

Pillar 1:

Establishment of a contextual problematization that has relevant impact on social structures but at the same time is narrow enough to be sufficiently analysed within the context of this dissertation: socio-technical transformation research.

Besides embedding the research in the above mentioned rather theoretical elaborations on transformation, scholarly application and use of societal transformation concepts in empirical-centric studies have also seen a sharp increasement within the scientific community. Due to the wide range of concepts that include diverse perspectives such as economic market dynamics (e.g. Alvord et al. 2004), organizational perspectives on government and civil society, or sustainability adoption to natural risk scenarios (Thaler et al. 2019) it is of crucial importance to first narrow down and specify the contextual framework for empirical research on societal transformation. This process becomes even more relevant when embedding the research in fast changing settings that can be found in many countries in the Global South. For this dissertation, the contextual framework evolved from the first research trip to Lusaka (Zambia) and is focused on technological innovation and its interdependencies with social structures in the Global South that can be characterized and analysed by looking at them as socio-technical systems. For more information on the study site and the examined socio-technical structures are discussed in the methodology chapter of the article "Production Environments of Digital Innovations: A Scalar Perspective on Cultural Legitimacy in Zambian Coding Networks".

Pillar 2:

Contextualization of the dominant 'drivers' and its transmitters that determine the overarching direction of the transformation process within this contextual problematization: digitization and digital innovation as driver of transformation in the Global South.

The second pillar refers to the targeted focus on production environments of digital innovations with its relevance for understanding technology's role in transformation processes of social settings as drivers of change. digitization here refers to new practices that evolve from the conversion of analogue to digital data and processes. By forging, shaping and influencing transformational drivers, digitization and generally an increased structural exposure towards the internet form the overarching institutional landscape of this study. In this regard, the production and inherent logic of technology has influence on its impact once implemented. Instead of analysing case studies that decipher and unscramble these impacts, this work instead aims at understanding how the development of innovations is influenced and how we can better understand social structures that are embedded in technical solutions. To understand these dynamics this dissertation builds on scholarly work on network innovation and network science and its relevance for transformation processes.

Pillar 3:

Particularization of a geographical framework of place and scale in a geographic network science scheme: relational network approach to innovation spaces/niches in the Global South.

Lastly, to connect these two domains, the theoretical part of this dissertation is augmenting relational space and scale approaches and concepts from network science serve as foundation for selected methodology. In combination with the socio-technical innovation framework that is discussed in the next chapter it forms a comprehensive structure for the embedment of empirical research. The specific study side is narrowed down to production environments of digital innovations (innovation hubs and innovation networks) in the Global South, with one study focusing on Zambian coding networks,

while a second study analyses three interconnected (digital) innovation networks from Uganda, Ghana and Zambia. The third study addresses the conceptual level and discusses the potentials, pitfalls, and a selection of prior scientific work to be considered that are relevant when transferring the MLP to the development context.

By discussing the details behind these pillars, the next two chapters on socio-technical systems, the Multi-Level-Perspective and drivers behind innovation and innovation networks in the context of societal transformation constitute the groundwork for the main arguments of this dissertation which are followingly discussed in connection to the three empirical studies.

1.2 Socio-Technical Systems & the Multi-Level Perspective

The following chapter will further elaborate on the first of the three pillars. By highlighting the inherent logic behind the concept of socio-technical systems in the context of sustainability transformation, it sets the baseline for the later discussed connections between innovation networks and societal transformation that is influenced by technology.

As stated above, analysing societal transformation under the scope of technical innovations requires a systematic framework that includes both social and technological influences. This socio-technical perspective has its advantage when highlighting interactions between social systems (value systems/norms/belief/organization as discussed by O'Brien & Sygna (2013) above) and technical systems (soft- and hardware). Because of these interactions, the technical installations are not only altered by the social environment they are introduced to, but in reverse also inflict change on it.

According to early scholars like Hughes (1983), advancing theses with reference to a technical change to be successfully implemented (normative of the transformation's driver), the social environment has to a) be suitable for the change to work as intended or b) change the necessary subsystems of itself to be suitable. In other words, early work on the interdependency between social and technical systems highlights that the social environment plays a key role in understanding whether a desired transformation process

(initiated through a certain technical agenda) is feasible and in reverse which factors hinder the progress or stand in fierce opposition to it. From a strongly technical deterministic perspective, Hughes (1983: 79) calls these hindrances and oppositions "reverse salients". They are social or technical sub-systems that do not "develop sufficiently" and "prevent the technology system [from] achieving its target development. […] Reverse salients can be technical elements such as motors and capacitors of an electric system, or social elements such as organizations or productive units (Dedehayir 2009: 574). Reverse salients therefore play a key role in the pathway, pace and (desired) success of a deliberately initiated transformation process and again illustrate the interconnectivity between social structures and technological innovation. In recent years, this school of thought is prominently represented by the term Socio-Technical System that was coined by the famous Travistock School in London (Trist 1978) and is widely used amongst both transformation and Science and Technology scholars. In contrast to the old prevalent technology focused approaches that analyzed changes in social structures merely through the deterministic way of technology itself, or the social science perspectives that did not include any relevant technical insights, the notion of socio-technological systems highlights the reciprocity between technology and human interactions (Ropohl 1999) without a prescribed normative focus on intended change. It argues that with the percolated integration of technological structures in everyday lives, societal functions must be understood in relation to technology and vice versa. Geels (2004: 900) therefore defines socio-technical systems "as the linkages between elements necessary to fulfil societal functions". In this regard, viewing socio-technical interactions from a systematic perspective offers an advantage in analyzing transformative processes because, as highlighted above, transformation is defined as a fundamental change in a social environment rather than a minor adjustment of a specific reversal salient. It further pinpoints technologies' missing ability to achieve these societal functions on its own (Leonardi 2012) and emphasizes that the constitution of a functioning system depends on the combination between human agency (socio) and technological components (technical). This theorization of the interplay between social and technological systems therefore offers new approaches for research on societal transformation as it acknowledges both perspectives without depreciating or overstating either one.

A Socio-technical system that fulfills societal functions is a specific set of elements, that are manifested in their established configuration. Once established, these systems include a wide variety of perspectives such as technical infrastructure, social routines and behavior pattens (Geels 2002). In return, the configuration of these elements forms a durable systematic bond in terms of stability that only enables incremental and path dependent innovation within the system itself (Geels 2002). Derived from this perspective, societal transformation only occurs in unison with changes in socio-technological systems and is not detached from there. To understand societal shifts, transition scholars therefore introduce the Multi-Level Perspective (MLP) approach that includes several layers of structures, which influence transformation processes. As illustrated in figure 2, the MLP consists of three major levels: landscape developments (macro), socio-technical regimes (meso) and technological niches (micro). It is important to note that these different levels follow a

The landscape as overlapping level incorporates deep structural arrangements and trends such as e.g., capitalism, climate change or wars. Its external context constrains direct interaction with actors and therefore makes it very resistant to change. It functions as a penetrative influence for the regime and niche level and only changes or adapts gradually over long time periods (Geels 2002).

The regime is characterized by current organization and structures of a societal function that consists of predominant and assertive rules, institutions and technologies. It is the combination of a technical and a social regime, incorporating them into a stable system that reinforces similar and complying dynamics (Fuenfschilling & Truffer 2014). Rip & Kemp (1998: 340) define a technical regime as "the rule-set or grammar embedded in a complex of engineering practices, production process technologies, product characteristics, skills and procedures, ways of handling relevant artefacts and persons, ways of defining problems; all of them embedded in institutions and infrastructures". Social regimes on the other hand highlight human actions and are defined as the outcome of organization and cognitive routines (Geels 2002). Together they enable or constrain activities within communities and act as a barrier for new technological and social innovations (Papachristos 2011). In the MLP transition framework, the last level is

therefore dedicated to alternative niche spaces that are defined as the receptacle or locus for innovations, which stand in competition to established regime arrangements. Niches are characterized by their sheltering function from regulatory influences and other market and social dynamics (Shot & Geels 2008). For this reason, they provide spaces for supporting networks and create environments, where innovations can be prepared for wider acceptance. Due to the strong anchorage of socio-technical regimes, innovations that derive from niche environments often rely on landscape developments that open doors for new opportunities (Geels 2011). A famous example for a socio-technical shift via niche and regime categories is the ongoing renewable energy transition. While fossil fuel structures are still dominant in energy production, innovations that were previously neglected, such as photovoltaic or changed energy consumption patterns by actors, have experienced a sharp rise due to the window of opportunity created by the landscape development of climate change (Strunz 2014).

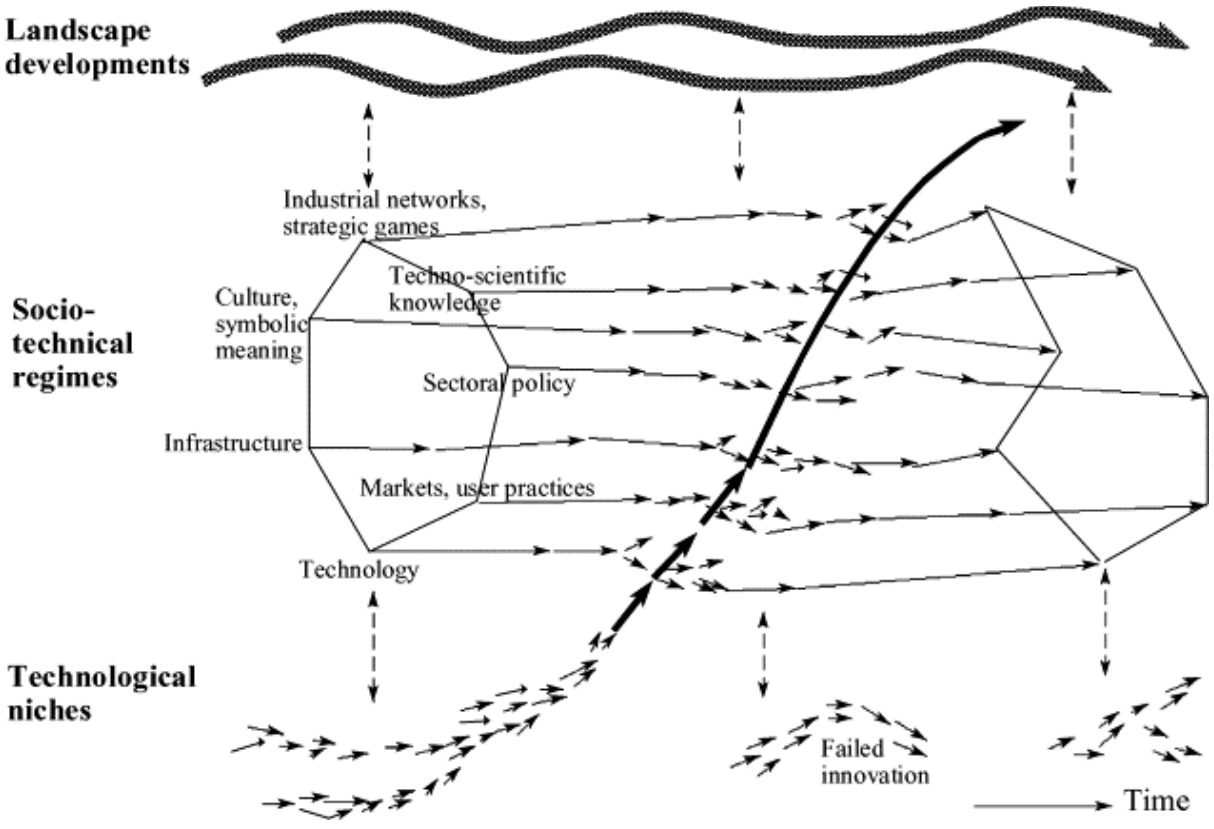

Figure 2: The Multi-Level Perspective (Geels 2002)

Besides the fulfilment of societal functions and transition dynamics through the MLP, the socio-technical system approach further highlights an aspect that can only be analysed when looking at technology and social structures as a dynamic interplay. Namely, the embeddedness of social structures within technological applications and appliances that are inserted during the production process of technologies. Monteiro and Hanseth (1996) showed for example that the diffusion of standards in technical communication systems are not neutral. Instead, social patterns, created by social actors, institutional arrangements and very specific work practices, are embedded in the technical structure itself and therefore "buried deep in 'technical' details they inscribe anticipations of individual, organisational and inter-organisational behaviour" (Monteiro & Hanseth 1996: 326). While this example aligns with research on promoted user experience and intentional design of user interfaces (Benyon 2019), there are also studies that discuss social embedded structures within digital organization systems and their effect on power relations and information distribution. Graham et al. (2015) for example link large editing content creation networks within the core structure of how Wikipedia works to the domination of knowledge production about smaller networks. These participation dynamics are part of how Wikipedia is organized and leads to what Grewal (2008) call "network power", a restricting characteristic of networks of knowledge that are inevitably constraining towards specific social groups.

The two examples again highlight the interplay between social structures and technological systems and show how understanding societal change under the influence of technology has evolved as a relevant topic in transformation research.

With the knowledge of how new technical innovations are created and promoted in niche environments, and at the same time human actors behind innovations translate social structures into technology itself, new research perspectives on societal transformation emerge. By focusing on the invention and production of technology and conceptualizing these makerspaces as niche environments, one can better understand how technology and societal transformation collude and interact.

As concluding summary, the socio-technical system approach offers two relevant research perspectives for analysing societal transformation under the influence of technology:

1) By highlighting the interdependencies and interactions between social and technical structures, *linkages between both of those arrangements* form the foundation for systems that fulfil societal functions. These socio-technical structures and functions can be theorized in the Multi-Level Perspective that is especially valuable when looking at transition phases as they appear in societal transformation processes under the influence of technology.
2) Technology is not ready made or neutral but instead contains social structures that are the result of its production environment (social actors, institutional arrangements, work practices etc.). These production environments of new technical innovations are found in niche settings where new technical ideas are embedded in a protected or insulated habitat.

2. Network Dynamics: Drivers of Technological Innovations

The second and third theoretical pillow of this dissertation broach the issue of the contextualization of the dominant drivers and its transmitters that determine the overarching direction of the transformation process and translate into innovation environments as drivers of transformation in the Global South. Because innovation does not happen in isolation (Boschma & Frenken 2009), networks as relative space and scale connections are emphasized as key theoretical concepts.

Built on the previously discussed importance of innovation's production environments, the research is narrowed down to understand *how innovations come to place and which influences ultimately drive the innovation processes*. As technology in socio-technical systems inherits social structures (see e.g. Graham et al. 2015; Monteiro & Hanseth 1996), transformative impacts can be investigated and evaluated from two perspectives. First,

from a traditional social science point of view, there are numerous studies on how the implementation of new technical innovations create dynamic transformation processes within social structures. This holds especially true when the research was conducted in the Global South (c.f. Unwin 2017). Malaquis & Hwang (2016) for example investigated how mobile banking and trust come together in different social setting and therefore highlighted, that different social actors generate different outcomes from the same implemented technology. Another research example from Park et al. (2009) examined people's adoption and use of digital library systems and showed how different perceived ease of use resulted in contrasting usefulness of the system. With this approach to research on socio-technical systems, the main focus lies on the implementation of an already fully developed technology such as mobile banking or a digital library. It often uses social science perspectives on how people react and interact with technology, without accounting for the social bias within technology itself.

The second research approach developed in this thesis therefore draws on a more holistic technological framework that emphasizes the interrelation between innovators and their technical products. Drawing on the above discussed socio-technical system relationship between technology and social structures that fulfil societal functions, this angle identifies two major baselines that extend current scientific knowledge. First, it expands the research focus to the previously neglected formation and development of technological innovations. Second, it fosters accentuation on drivers behind new technologies as well as on their transmitting forces and structures, yielding influence long before implementation takes place.

The key research questions therefore change from "what are the effects of technological innovations in societal transformation processes?" to

"How does the production environment behind the formation of new socio-technical systems influence societal transformation processes?"

Or in other words, it highlights innovation processes and its drivers with an emphasis on the normative social bias of technology instead of use cases and implementation effects.

In a formulation more tailored to the research context (Global South, sub-Saharan Africa) and research object (digital technologies and their development and implementation environment), the central research question therefore becomes:

"What is the influence of the production environment in the emergence of new socio-technical systems from the digital domain on social transformation processes in the context of the Global South?"

Innovation, especially of technical nature, is not the product of a single entity but instead arises due to an extensive network of human and institutional actors (Greenacre et al. 2012). The same way socio-technical systems only fulfil societal functions by integrating a wide variety of stakeholders, organizations and underlying cultural practices, innovations are shaped from complex and knotty connections (Kline & Rosenberg 2010). Analysing a single entity (e.g. companies, governmental bodies or single persons) is therefore not enough to understand the innovation process and with it its impact on the innovation output. Alternatively, the driving forces can be conceptualized as a network of innovation. Boschma & Frenken (2009) state that a key question in innovation research is to resolve the presence or absence of links between a variety of stakeholders and therefore focus on the relationships between different points of intersections. Based on the concept of proximity, defined as the similarity of attributes of nodes in a network, they argue that by understanding the connections and relations one can find out more about influences in innovation processes (Boschma & Franken 2009). This approach to innovation networks is based on geographical scholars who over the last decades have developed a relational understanding of space and scale (see Massey 2005; Massey 2013). As demarcation from container concepts that declare space as absolute with clear borders and apportionments, relational approaches shift away from a materialistic ontological viewpoint that puts emphasize on space's real material existence as a result of socio-political mechanisms and natural laws (Murray & Overton 2014). Instead, relational space argues for an idealistic perspective, defining space as a frame of references where the relative location of entities to each other form network structures (Massey 2013). In this theoretical conceptualization, scale is then not construed as a hierarchical concept such as a ladder or concentric circles that would require clear boundaries. Instead, scale is delineated as categories through

which the world can be analysed and is understood as a fluid process (Murray & Overton 2014).

This space and scale approach is the foundation for a holistic network science perspective that besides analysing mere attributes of entities also shifts the centre of attention to their relative connection and position within a network. Hence, an abstraction of a social network exists of nodes and edges, where a node is a representation of an entity that stores data in form of information. Nodes can be individuals, institutions or any other form of organization. Nodes are connected to each other via edges that function as a link between nodes and can also store additional information in the form of weight. This way, connections between nodes can be classified as relatively strong or weak (Robins 2015). Translated to innovation networks, nodes represent any individual, institution or organization that is exerting influence on the emergence of ideas and the manufacturing of products from first thought to final output. The drivers behind innovation are therefore conceptualized as relative influences within these innovation networks. The positions of nodes, connections and weights of linkages enable insights into the social bias of technological innovations and therefore provide an original approach to do research on societal transformations processes.

These theoretic foundations for innovation networks and their space and scale embedding must ultimately be seen in the context of the Global South. The most important keyword in this sense is contextuality. In the field of geographic development research, there was an early recognition that copying solutions from outside creates dependencies and superficially disregards the different contexts of implementation (Glassmann 2011, Taylor & Broeders 2015). Accordingly, many well-intentioned projects 'fail' to transfer contexts. Local structures, both socio-economic (e.g. social norms) and physical factors (e.g. access or availability of resources) are therefore of elementary importance in the development of technological systems in the Global South. The research object of the production environment is therefore based on the 'local', which takes contextual applicability into account when designing and utilizing new digital technologies. Or, in other words, the research questions lastly address the paradigm that technology should be given a deep-

seated embedding in local structures through local development (Bhadauria et al. 2018, Bailey & Osei-Bryson 2018, Unwin 2017).

3. Methodology

This work initially consists of three articles published in scientific journals. While the first two are each based on empirical data, the third is a so-called "perspective article" that has a conceptual and thus theoretical horizon based on the previous work and an intensive literature review. The methodology and methods utilized to collect empirical data is as diverse as these individual articles. In this Methodology chapter, the approach of the research is discussed, and the process of data collection and data analysis is set on a methodological foundation. While the first article, "Production Environments of Digital Innovations: A Scalar Perspective on Cultural Legitimacy in Zambian Coding Networks," is based on methods that can also be described as classical social research tools (semi structured interviews and its evaluation), the second article, "Influence in online spaces: mapping Twitter networks of innovation hubs," is focused on large quantitative data sets and computational data science approaches. Accordingly, this methodology chapter is also divided into two main parts. First, into a brief discussion of the basic ontological and epistemological position in the form of critical realism and the hermeneutic circle. Second, into a part that discusses research approaches from data science and here especially network science. Finally, this chapter explains why the research questions presented in the theory section are deemed adequately answerable by the selected methodology.

Unlike in classical doctoral dissertations, the methods (instruments) and study sites are also presented as a separate chapter in the respective articles, which is why this methodology chapter is structured as a linking element rather than a repetition. Specific information on the study sites, data acquisition in Zambia, stakeholders and explicit structure of the interviews, digital data collection and data analysis can be found in the respective parts of the papers themselves.

3.1 Critical Realism and the Hermeneutic Circle

The theory of this thesis, discussed in detail above, assumes that the duality of technology and social systems contribute to fundamental transformations in societies. While other research perspectives in this context increasingly look at the implementation and concomitant changes of social systems through technology, a more differentiated perspective is served in this thesis. Deriving from the theoretical basis of the MLP and socio-technical systems, a focus is placed on the developmental environment of technological innovation and its representation within the niche concept of the MLP. Or in other words, it looks at the drivers behind technological innovation in a certain setting, here the Global South. The second theoretical cornerstone in this setting is the conceptualization of scale through relational networks and its usefulness to describe social entities. In doing so, the dissertation explores the questions of how the production environments in the context of the Global South (represented by relational social networks) influence new formations of socio-technological systems. Methodological considerations and, based on them, the final theory and individual methods therefore aim to reveal these networks behind technologies and make them analysable.

As with any scientific work, the question "how scientists know what they know" (Wenning 2009: 1) stands at the beginning of any gain of knowledge. First, a short section on critical realism and further on the hermeneutic circle will address the methodological foundation of this work that not only functioned as basis for specific methods but also for differentiating various theoretical discussions.

The foundation of critical realism argues for a world that consists of generative mechanisms that exists "independently of human interpretation, knowledge, enactment, or discourse" (Hedlund-de Witt 2016: 4). At the same time, it acknowledges that knowledge remains within the oscillating existence of production through social lenses and the existence "'of' things that are not produced by humans at all" (Bhaskar 2013: 21). Knowledge on generative mechanisms (real things) can therefore only be acquired through socially embedded interpretation and construction. While sharing the positivist view of an "objective world, generalization, and in finding causalities" (Alvesson & Skoldberg 2009: 40), critical realism seeks to additionally account for unobservable

mechanisms through a constructive lens. In critical realism the ontology is structured on three levels: the real, the actual and the empirical. While the real stands for generative mechanisms that cause events, the actual can be described as precisely these events, regardless of whether they are observed or experienced. With the empirical category, critical realists ultimately characterize the cases that enable the acquisition of specific, contextual knowledge through these possible experiences or observations (Alvesson & Skoldberg 2009: 40-43; Hedlund-de Witt 2015: 5-6).

For the explicit investigation scenario, this means that the actual, which arises as a result of generative mechanisms, can be observed and experienced through empirical data acquisition. At the same time, however, critical realism also reflects the failed completeness or flawlessness that inevitably arises due to the social embedding that obscures the view of the real. In view of the interpretation of knowledge in social research, the process of acquiring knowledge can therefore not be carried out without constant critical reflection on one's own position (Rennie 2012). A research approach tackling this gap between researcher and the real is the hermeneutic circle, which constantly ensures that knowledge is reflected, analysed and reevaluated throughout the research process.

In the context of qualitative methods, hermeneutics describes the need to understand the specific context in which the analysis of the real takes place (Aksoy 2016). Since knowledge is not neutral due to this context and has an influence on the actual interpretation, the applied hermeneutic circle works to reveal this previous specialist knowledge so that the research process and the results lead to a comprehensible, reproducible result (Aksoy 2016: 117). Their value in qualitative social research thus lies in the ability to contextualize knowledge in higher-level mechanisms and contexts and vice versa. Through the "spiral-like" approach, which arises through constant reflection and questioning of one's own position in relation to the object to be examined, one's own prejudices, prior knowledge and biases can be reduced. This creates a more accurate and particularly reproductive view of the real and the generative mechanisms behind it.

In the course of this dissertation, the methodological foundations of critical realism and the hermeneutic circle were relevant in two ways: first, in the continuous development of the theory-guided part, and second, in the classification of the empirical data collection

and subsequent analysis. For differentiating and interpreting the MLP, drivers and scale/networks, niches for digital innovations in the Global South and their inner dynamics were seen as manifesting ("the real") existence through social interactions ("the actual"), which becomes conditionally understandable through an empirical uptake ("the empirical") shaped by the researcher. Hence, the conditionality depended on the reflection of one's own positionality on the one hand, and on the wilful focus on influencing factors in social network on the other hand. This focus was not predefined as a fixed objective before the fieldwork, but developed through observations, experiences, and further literature work. This further development process of the theory part, guided (or influenced) by the hermeneutic circle, can be described in retrospective with the following milestones:

1) Exploratory start into the theory of societal transformation with a rough starting concept according to Feola (2015): *prescriptive and emergent*

2) Integration of the "digital perspective" by focusing on socio-technical systems

3) Specialization on MLP and driver behind technological innovation

4) During the first empirical data acquisition in Lusaka, Zambia: more detailed focus on niche (production environment of digital innovation) and cultural legitimacy

5) During the second empirical data acquisition 12 months later: more detailed focus on network/scale perspective in MLP transformation framework.

Accordingly, the results of the analysis of the empirical data - which in turn are structured based on the evolving research questions derived from the changing theory section - only allow singular conclusions to be drawn about the sub-areas mentioned above. They therefore do not claim to provide a complete and conclusive characterization of transformation processes under the influence of digital technologies in the Global South, but rather represent an excerpt of a situation at a particular time and in a particular context.

3.2 Towards geographical and computational network science methods

The themes around which this research revolves have had a special relationship to each other from the very beginning. On the one hand, the digital, which is physically tangible through underlying hardware, but still requires its own quantitative and analytical approach for research in the optimal case. On the other hand, the reality of life of the network actors in the physical space, which can very well be made accessible for scientific work via classical social research and case studies. Accordingly, the methodology of this work is also diverse and cannot be squeezed into a simple pattern. While some empirical results and their analyses are based on social science observations "on the ground", other data was prepared by web scraping, gathering data from APIs and the merging and cleaning of different quantitative databases that subsequently were analysed and interpreted by algorithms.

The discipline of addressing social phenomena using Computer Science methods is therefore also described in the sciences as Computational Social Science (CSS). Computational Social Science is situated at the "intersection of the Social and Computational Sciences, an intersection that includes analysis of web-scale observational data, virtual lab-style experiments, and computational modelling" (Watts 2013: 5).

Like 'classical' social sciences, this discipline views social structures as an effect of interactions between actors, according to Keuschnigg et al. (2018). Since these in turn are interrelated in complex social structures, tools from the CSS can help to collect the mass of data for situation description in a structured form, while analysis and interpretation take place on basic principles of the social sciences. The added value of methods from computer science gained through computing power and new information access is thus embedded in methodological and theoretical frameworks of the Social Sciences.

In this work, the methodological foundations and the CSS methods are applied in relation to innovation systems. Specifically, it is about modelling innovation systems as networks in which social actors relate to each other and exert influence on the activities of the network. Activities here range from the design of narrative to selection of technical development tools to thematic sectors that are considered necessary, or advantageously exposed, for innovation projects through digitization. In the modelling and subsequent

analysis of these activities shaped by social actors, two concepts are of central importance: Space and Scale. Starting from a geographic perspective, they form the core framework of a research process I coin *geographical network science*.

From a geographical perspective, there are many different approaches to defining space and making the concept useful for empirical research. The approaches range from an economic perspective, in which space is seen as a dissemination of routines (Boschma et al. 2017), to perspectives that define space as a relation between objects (Malpas 2012). In this work, space is seen as just that: a geographical entity formed by the relational linkages of many different entities and thus not describing an absolute, bounded space that would contain a clear inside and clear outside. In terms of linking this to the research subject, this means that digital technology innovation environments in the Global South cannot be traced back to delimitable areas of a map, or delimitable physical environments. Instead, they can be traced to the relationship between the actors who are involved in the innovations as well as technical structures that determine these linkages. Both transcend the analytical possibilities of absolute space. This is the first pillar to which geographic network science methods must be tailored: Spaces are not to be understood in absolute terms, but through relational linkages of entities in network structures.

The same relational approach runs through the related conception of scale. In the classical sense, scale is understood as a hierarchical order, which can be mapped on analytical levels, for example, as local, regional, macro or global (Rauch 2003). In this logic of a ladder there is a clear successive order, which only have a conditional, or limited significance for networks. Therefore, this dissertation does not consider networks as static, in which there are clear dividing lines and successive paths of influence, but as a relational concept. This outlines a dynamic network of interactions and actors that do not necessarily need to be analysed hierarchically and thus do not cease to exist when crossing selected space demarcations (Massey 2013, Murray & Overton 2014). The second pillar relevant for geographic network science methods is therefore the notion that scale in networks is not static and based on hierarchy. Instead, each entity has the theoretical possibility to influence or be influenced across absolute scales. Thus, the focus is no longer on the static position within a scale category, but on the relative position within a defined network and

the associated sphere of influence. In practical terms, this means that through their activities in a particular geographical narrow location an actor or institution can influence structures and actors in distant contexts, without influencing actors or institutions in their own direct local or regional environment. Thus, if scale was conceived as a ladder, individual rungs would be skipped, and a hierarchical analysis would no longer work. Methods of geographic network science, which are used in this dissertation, must therefore meet this demand.

Hence, in addition to classical observations and interviews from the toolbox of the social sciences, methods from CSS are used in this work, with which digital networks and their internal compositions and dynamics can be newly mapped and analysed. For some analyses, this means extracting meta-information such as geo tags, names, texts, or timestamps from large amounts of network data, relating them to each other, and then interpreting them to address the presented scientific questions. For other analyses, this thesis worked from CSS point of view with algorithms that reveal the relationships within networks. In order to avoid duplication to the method chapters of the respective articles, the following section is specifically explaining the properties of the major two algorithms that were used but not explained in greater detail in the published articles.

1) Modularity Algorithm

The Modularity Algorithm measures the density of connections in a network. This creates individual modules (communities) in which individual entities have many connections to each other, but few connections to the outside to other modules. Accordingly, the Modularity score provides information about the density of modules due to the large number of connections of their entities.

The algorithm is structured as follows:

$$Q = \frac{1}{2m} \sum_{ij}^{n} (A_{ij} - \frac{k_i k_j}{2m}) \delta(C_i, C_j).$$

"[W]here m and n stand for the number of edges and nodes, respectively. A is the adjacency matrix, if two nodes are connected, the corresponding Aij represents the weight

of connected edges between them, otherwise Aij = 0. ki and kj are the degree of vertex I and j. Ci is the community vertex i belongs to. δ(Ci, Cj) is a sign function, i.e. if Ci = Cj , δ(Ci, Cj) = 1, otherwise δ(Ci, Cj) = 0. The fraction, Pij = ki kj 2m , stands for the expected number of edges in the corresponding null model. The function δ only makes sense when vertex i and j are in the same community" (Zhou et al 2012: 639).

As already explained in chapter 2, modelling an innovation network in nodes and edges enables an analysis of the quality and quantity of the existing connections between the individual actors. Nodes represent an individual, an institution, or another form of socially structured organization. By weighting the edges as connections by the modularity algorithm (Aij), nodes that are closely connected can be identified and classified into a common cluster according to their strength or weakness (Robins 2015). On the one hand, together with a further analysis of cluster groups (modules), this enables a thematic classification, which is essential for the understanding of the nodes in network. On the other hand, the algorithm makes it possible to understand which nodes cluster together thematically and how relatively close or relatively far they are positioned in relation to other modules (communities). Therefore, this also reveals the closeness or distance of entire clusters to each other.

2) Betweenness Centrality Algorithm

The Betweenness Centrality Algorithm was used to analyze the power over information, practices and opinions of individual nodes within the innovation network. The algorithm is structured as follows:

$$g(v) = \sum_{s \neq v \neq t} \frac{\sigma_{st}(v)}{\sigma_{st}}$$

"[…] [W]here σ_{st} is the total number of shortest paths from node s to node t and $\sigma_{st}(v)$ is the number of shortest paths from s to t going through v" (Barthelemy 2004: 164).

What at first appears to be a very simple algorithm that calculates the number of shortest paths leading through a given node has turned out to be a very effective method for the analysis of complex networks. This method is based on the insight that not all nodes in a network have the same relevance. If we assume, as shown in figure 3, that the removal of a single node (e.g. node A) would not have the same consequences as the removal of other

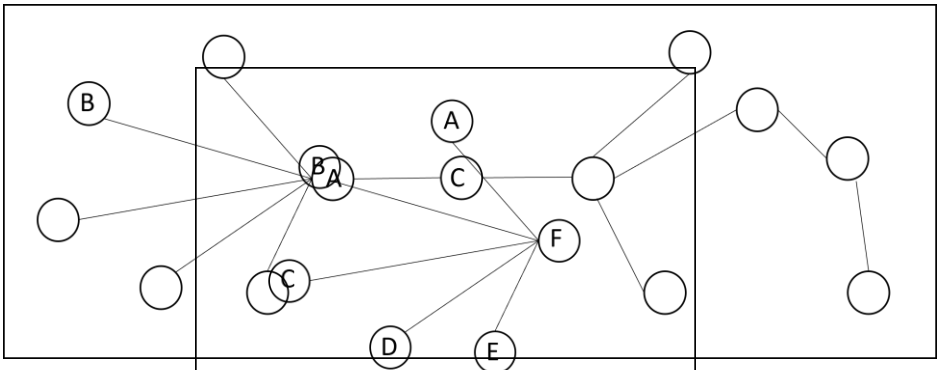

Figure 4: Examplary dependent network A-C

Figure 3: Exemplary A-F network

nodes (e.g. node F), the meaning of centrality becomes clear. Here, centrality is understood as a quantity that can be determined individually per network. E.g., how many other nodes would also lose edges due to the removal of a single node. However, the limitations of a simple centrality calculation become apparent when applied to more complex networks. As shown in figure 4, node C has a very low centrality of 2, but its omission would form two clusters in the network, which would be completely separated from each other without this node. Its relative importance is therefore many times greater than the simple centrality value can express. Betweenness centrality, on the other hand, also includes the shares of the shortest paths that lead through a single node (Barthelemy 2004). The resulting value is therefore useful, as in the case of this work, to determine the accurate meaning of nodes for other nodes within the network. Specifically related to this work, this means that individual nodes can act as catalysts, or multipliers, and thus have the power to carry information in different radii within the network. The information, practices, and opinions represented by these nodes accordingly have greater reach and significance (Blondel et al 2008). Understanding first which nodes have higher Betweenness Centrality, and second how they use that power, provides valuable insights into why and how certain technologies are developed and also the context in which development occurs.

Besides the modularity and betweenness centrality algorithm, many other CSS methods were used in the data acquisition, the exploration phase of the data sets and the further analysis. These are based on descriptive sorting and ranking (e.g., filtering by quantity of activities of individual nodes), as well as statistical significance (e.g., bi- and n-grams in the linguistic analysis of texts) and on visualization efforts for either easier comprehension or for the final presentation. All code and methods used can be viewed at https://github.com/DanSchmitt/Influence-in-online-spaces-Mapping-Twitter-networks-of-innovation-hubs.

3.3 Semi-Structured Interviews

A total of 31 semi-structured interviews were conducted, especially for the first article and for the qualitative/contextual supplement of all other data. In addition to personal background, education and work experience, a special focus was placed in these interviews on the position, activities and influences of coding networks for one's own programming and, in the broadest sense, innovation work. Another focus was the question of the extent to which existing networks (both digital and analog) shape one's own understanding of and debates on technological innovation and the extent to which differences between members of the networks and outsiders (such as family members, friends, or work colleagues) are discernible from the subjective perspective of the interviewees.

The interview guides were designed to be informal and more like a conversation between peers than formal and hierarchical. The focus, as suggested by Longhurst (2003), was on the open-ended response of the interviewees in their own words. Thus, a simple 'yes' - 'no' response was avoided as much as possible. Semi-structuring helped to prevent the conversation from stalling by pre-determining the thematic fixation of the prepared questions and also to be able to readjust if the interview moved to distant topics (Flowerdew & Martin 2013). After the interviews were transcribed, they were schematically coded using SPSS, anonymized, and the relevant passages were linked across interviews.

4. Integration of empirical and conceptual work: the articles

In this chapter, the three articles that serve as the basis for this thesis are placed in the overall context of the work. In each case, a uniform structure is followed. First, the *background* and larger context of the research is presented. Second, the *integration* of all three articles is discussed in relation to the overall context and the overarching research questions on production environments of digital technologies in the Global South and their influences on transformation processes.

4.1 Article I — Cultural legitimacy and the production environment of technology in the Global South

Title: "Production Environments of Digital Innovations: A Scalar Perspective on Cultural Legitimacy in Zambian Coding Networks"

4.1.1 Background

With first the wide spread of landline technology, mobile phone communication, the rapid dispersion of the internet, the emergence of sensor networks and later advancements in cloud computing, the term "digital economy" entered daily linguistic usage. It is defined as economic activity based on digital technologies and is widely accepted as one of the most important drivers of change in Africa (Bukht & Heeks 2017).

The digital economy is the amalgamation of several general-purpose technologies (GPTs) and the range of economic and social activities carried out by people over the Internet and related technologies. It encompasses the physical infrastructure that digital technologies are based on (broadband lines, routers), the devices that are used for access (computers, smartphones), the applications they power (Google, Salesforce) and the functionality they provide (IoT, data analytics, cloud computing)" (Dahlman et al. 2016: 11).

As a key contributor and disruptor of many developments in economic and social systems, digital applications based on the incremental availability of the physical infrastructures mentioned by Dahlman et al (2016) above have therefore seen unprecedented growth during the last decade. Platform companies like Google, Facebook, SAP or Weibo have quickly risen to multinational powerhouses and applications like WhatsApp that started as small start-ups with just a handful of employees are now connecting several billion people across the globe. It comes as no surprise that the potential these digital technologies offer in combination with their disruptive nature and often unknown effects on social structures sparked interest from a wide variety of research fields.

Amongst them are ICT4D scholars, who are investigating digital technologies in the Global South and their effects on sustainable development efforts. With a long tradition of so called 'tools for development' originating outside of their actual implementation environment, the discussion of contextual application and the overcoming of postcolonial influence in the progress of the declared underdeveloped countries has been widely debated in this research field (Andoh-Baidoo 2017). In his work on ICTs in the development context, Unwin summarizes one of the key principles of ICTs in the development sector with the following words:

"Everything depends on context and culture. There is […] reasonably wide international agreement that stability is generally preferable to instability, and therefore that reducing the potential of ICTs to be used in too disruptive of a manner is desirable" (Unwin 2017: 186).

Further he elaborates on the divide between what he frames as 'best practice' and actual context specific solutions:

"I believe passionately that in most cases there are no such things as best practices because of the need to adapt such practices to local contexts. Instead, we need to offer multiple examples of good practices so that individuals, organizations, and countries can develop their own local and context-specific solutions, practices, and initiatives that will serve the particular interests, rather than the interests of those propagating best practices!" (Unwin 2017: 101).

What is striking about the work of Unwin and many other scholars is that they focus heavily on the local level and emphasize the importance of contextual digital solutions developed by actors in the implementation environment rather than by outside experts. Or in the words of Endrit Kromidha on the official UNESCO chair for ICT4D blog:

"There is a tendency in the developing world to adopt technologies, practices and models from the developed contexts without due consideration to the local contexts" (Kromidha 2017: 1).

This notion goes hand in hand with other famous technology theories, e.g. the Appropriate Technology concept, which targets technologies that are easily to be used and readily available for local communities and are therefore more effective in delivering its desired outcomes through higher legitimacy amongst the actual users (Pearce 2012, Schumacher 1973). Legitimacy of technology is therefore said to be created through local contextuality.

Legitimacy discourses as representation of linkages between technology and norm and belief systems derive from a problem-based perspective on societal transformation and emphasize social bottlenecks during introduction and growth stages of innovations under the scope of its adoption and usefulness (Geels & Verhees 2011). In this context, legitimacy is defined as "[…] a generalized perception or assumption that the actions of an entity are desirable, proper or appropriate within some socially constructed system of norms, values, beliefs and definitions" (Suchman 1995: 574). Digital technology as an entity is therefore measured against the backdrop of its ability to integrate in to the social structures of a targeted implementation environment. As transformation is a desired process within the practitioner community of the digital economy (digital = advanced, non-digital = in need of overhaul), new digital technologies have the complex and often laborious task of combing innovative ideas with existing social structures. For analysing such tension fields, Geels and Verhees (2011) propose the notion of cultural legitimacy.

Cultural legitimacy is defined as the linkage between technical innovations and the dominant cultural frameworks. Arguing from a performative view, placing emphasis on the manifestation of cultural frameworks through the performance of actions on stages that influence targeted audiences (Alexander 2004), Geels and Verhees (2011) further

discuss the production of legitimacy through framing struggles as an analytical concept to understand these linkages. In observing various efforts by different stakeholder in either making the relevant cultural framework compatible with technological characteristics or translating social structures into technical innovation, the created compliance between society and technology is specified as the main object of research. The creation process of new technologies is therefore always accompanied by involved actors, who frame technology in a particular way, targeted at influencing general discourses in their desired directions (Geels and Verhees 2011)" (Schmitt 2019: 531).

Hence, the article is embedded in the discourse around the creation and justification of essentially required cultural legitimacy and its accompanying frames and framing struggles during the production of digital technology. By connecting cultural legitimacy of the production process with the question of scale, the article focuses on the networks behind new technologies and how they construct and practice scale beyond a static local, national and global framework, which in return opens a new discussion on how narrow contextual digital technologies can actually be.

The analysed frames to promote new digital tools are drawn from fieldwork with members of coding networks, which are defined as institutional connections between individuals, who create new digital technologies by using programming languages. Such coding networks are enjoying growing popularity on the African continent because they effectively function as education communities within the dynamic and rapidly changing field of programming, which requires open-ended and ongoing learning. In combination with online forums such as Facebook, Github and Stackoverflow, they bridge the gap between formal university education, self-taught developers and other persons who are interested in coding skills and therefore reside at the heart of new digital innovations, especially in Africa (Schmitt 2019). In Zambia, the study area for this study, there are several communities that are classified as coding networks according to the above definition. For the case study, the focus lies on Lusaka and its highly connected developer scene, including regular meetings at the BongoHive Co-working and innovation hub, the local Facebook Developer Circle, Agora Code Community and members of the University of Lusaka's and Zambia's Computer Science Society.

4.1.2 Integration

Legitimacy is defined as "[…] a generalized perception or assumption that the actions of an entity are desirable, proper or appropriate within some socially constructed system of norms, values, beliefs and definitions" (Suchman 1995:574). According to Geels and Verhees (2011: 912), "cultural legitimacy of actions, innovations or ventures [then] arises from the creation of linkages to the existing cultural framework". The discussion on legitimacy in socio-technical transformation processes and its importance for newly introduced digital technology for specific contextual implementation raise several research questions.

- First, what are the legitimacy discourses and frames around digital technologies in Zambia?
- Second: Which influences within coding networks condition this specific determination of legitimacy?
- And third, what role does local context play in legitimacy discourses and how does the narrative of local contextual innovations persist against the actual process of legitimacy production?

In this integration section, the results of the article are evaluated against the background of the central arguments of this thesis. These three main questions thus reflect the central outline, addressing the perspective of production environments and influences during the creation of socially transformative digital technologies. First, I will elaborate on the actual frames promoted by stakeholders of coding networks and connect them to categories suggested by Geels and Verhees (2011: 914), namely "actor credibility", "empirical fit", and "micro-cultural resonance". These frames and analytical categories create interesting insights into the inner dynamics of the production environment of digital technologies and combine them with legitimacy from a social perspective of transformation. It therefore offers a valuable perspective on how inherent characteristics of technology are shaped through their social production settings. Built on this perspective, I further discuss the second question around influences that condition these frames as well as their cultural legitimacy. The influence production is analysed as network activity, hence connecting it

to the second major argument of this dissertation that is concerned with the social linkages that influence the production process behind digital technologies. Finally, I will discuss which effects the findings on cultural legitimacy have on contextual developments in terms of the ability of technology to promote transformation.

1) Legitimacy discourses and frames around digital technologies in Zambia

The research identified three frames targeted at promoting digital applications from within the coding networks in Zambia. First, digital applications as results of programming are seen as indispensable and a fundamental part of shaping the future. As the most reoccurring pattern, members of the coding networks all shared the view that digital technology is the most important driver behind change. Built on what Chandler (1995) coins "technological determinism", this frame highlights the stakeholder's opinion that technology is an indispensable condition for all changes in society. Inventing new digital technology is therefore associated with actively shaping the direction of societal transformation processes.

The second frame examines the idea that digital technology connects and integrates the Zambian society into a perceived and well-established global community of digital actors.

"This global community is identified as a conglomerate of […] stakeholders with no hierarchical or institutionalized structures that works on solving self-identified problems through the use of digital technology" (Schmitt 2019: 537).

These international communities are on the one hand easily accessible through a variety of online communication tools (forums, chats etc.) and function as a direct peer network to receive help and inspiration for projects. On the other hand, they gain momentum with the inclusion of famous individuals who utilize digital technology (e.g. Marc Zuckerberg or Elon Musk) that are not directly acquirable but represent aspiration and act as abstract role models. Because members of the coding networks often complain about being hindered instead of supported by their social environment, they flee to online spaces and find validation and confirmation in this global community, which in return has immense impact on the shaping of digital technology that is being developed in Zambia.

The third promoted frame highlighted in the article deals with programming as high-skilled work that enables self-determined career and life choices away from old and traditional influence structures. There are two major components of this frame. First, the ability to create new digital applications through programming is evaluated as a difficult and complex skill that only very gifted people are able to acquire. This can be seen from the fact that many coding network members in school and university have had above-average grades and have a reputation with friends and families for being exceptionally smart. Second, the ability to create computer code opens up new possibilities that conflict with more traditional professions such as lawyers, teachers or engineers, which are predominantly integrated into existing work structures. These new structures are associated with a high degree of autonomy and individual freedom that is connected to Western lifestyles and offers not only high salaries but also the advantage of being part of a cultural transformation movement.

"The skill of programming is therefore seen as the central aspect that determines between being forced to learn a 'normal,' more socially accepted, and traditional profession (such as medical personnel, lawyer, engineer, or teacher) and being part of perceived international and modern work opportunities." (Schmitt 2019: 540)

2) Which influences within coding networks condition this specific determination of legitimacy

If we understand legitimacy as the link between cultural frameworks and digital technologies, while at the same time the epistemological focus is on the production environment, the frameworks outlined above raise two questions. First, to what extent do members of coding networks influence social structures by promoting their own frameworks? And second, how can the frameworks affect inherent characteristics of technology itself?

In order to answer these questions in the special context of Zambian programming networks, the article addresses three categories according to Geels and Verhees (2011), which link legitimacy discourses with technical innovation. These are 'actor credibility', 'empirical fit' and 'macro-cultural resonance'. While the perspective of actor credibility examines an actor's status or perceived expertise when promoting frames, empirical fit evaluates the perceived compliance between actual measurable situations/events and the

frames. The third analytical category, macro-cultural resonance, ultimately links deep cultural structures such as dominant norm and believe systems and their perceived correspondence with the promoted frames.

Discussing the first question on influencing social structures through the promotion of frames in the context of developing digital innovations, the starting point is the consideration of actors' motives, incentives and catalysts.

The creation process of new technologies is […] always accompanied by involved actors, who frame technology in a particular way, targeted at influencing general discourses in their desired directions (Geels and Verhees 2011)" (Schmitt 2019: 531).

In this regard, analysis of actor's credibility painted a split picture, where one of the dividing lines runs strongly along the age structure of involved stakeholders. This can be paradigmatically exemplified by looking at families, who share connections to members of coding networks.

"Although it is reported that many younger relatives have a growing understanding of the value of computer science as an education, there is still a lot of opposition. In contrast to accepted careers like medical staff, engineers, lawyers, teachers and businesswomen and men, computer science is still seen as negative education choice with unpromising job prospects. According to veteran practitioners, this mainly stems from missing direct contact with technology and cultural resistance towards outside change of values and norms. Many programmers report that, especially, older family members actively complain about new technological trends" (Schmitt 2019: 541).

Compared to their own futuristic outlook and technological determinism, which emphasizes the inevitable necessity of digital progress, coding network members display profoundly different core assumptions about the necessity and urgency of digital technologies and their promotion in society. Similar results for division regarding digital technology can also be found by looking at different occupation. At the time of the research, industries such as insurance, banking, and consulting firms were supporting and encouraging digital innovators by demanding their skills and actively seeking connections with them, while government agencies in particular were said to be averse to

new processes of digital transformation. Deducted from those two examples from the empirical part of the article, the promotion of the three frames around digital technology outline two major battle grounds for digital technologies. One based on age and here especially in the family context, one based on professional opportunities that are either strong advocates of new technologies or actively prevent their implementation.

Embedding these exemplary findings to transition frameworks such as the Multi-level perspective, traditional structures such as families, governmental institutions and other well-established professions can be clearly characterized as regime components that oppose disruptive change. On the other hand, we see landscape developments such as wide accessibility of ICTs and the worldwide push towards advancing the digital economy, including the banking and insurance sector, which support and encourage niche actors in contesting those regimes. This is also highlighted in the analysis of empirical fit, where the article shows how international stakeholders (e.g. digital companies like Facebook) create exchange programs to further support and encourage members of coding networks in their work to disrupt established structures via digital technology.

The importance of new, non-traditional influences can also be supplemented by the analysis of macro-cultural resonance. What stands out is the strong relationship between coding networks members and internet culture, including online friendships, online education and an international nerd culture with regard to computer games, films and comics, which are often of little importance in their offline social environment (friends, families, coworkers etc.).

What are the key takeaways from this for the initial research question "to what extent do members of coding networks influence social structures by promoting their own frameworks"? As Alexander (2004) demonstrates, the performance of actions on stages creates cultural frameworks which try to influence social structures in their favour by manipulating the outcome of discourses around language organization, actions and self-conceptions (see as well Belina & Dzudzek 2009; Fairclough 1992; Johnson et al. 2006). The above highlighted frames and expounded framing strugglers are therefore categorical stages to understand cultural discourses around digital technology. Hence, the

demarcations between different professions or age groups, for example, illustrate disputes between regime and niche structures that compete over dominant positions regarding digital technology. This can be exemplified on the above discussed notion of technological determinism, which creates friction points on the core believe system of niche and regime actors. While the regime gives more weight to established business processes such as face-to-face meetings (Hardwick et al. 2012) or paper-based file systems in relation to disruptions from the digital economy, niche actors in form of members of coding networks evaluate digitization processes as inevitable and fundamental part of successful future developments. The same friction points can be documented regarding communication, where digital communication via chats is frowned upon by older family members, while at the same time young members of coding networks highlight its superiority over personal contacts or phone calls (Schmitt 2019).

The discussion on cultural legitimacy, including frames, framing struggles and perceived plausibility and salience in form of actor credibility, empirical fit and macro-cultural resonance, only emblaze on one side of the medal, namely making cultural frameworks compatible with technological characteristics. But additionally, it also offers a glimpse on the reverse perspective, translating social structures into technical systems.

The second question concerning the linkages between cultural legitimacy discourses, digital technologies and coding networks in Zambia therefore goes one step further in asking how the frameworks affect inherent characteristics of technology itself. While the research was not designed to fully answer this question, it nonetheless provides some interesting starting points and should therefore receive some short discussion in this integration section. In this research perspective, the basic assumption is that a technical system is not neutral but rather is embedded in a socio-technological context and thus also has built-in social components (Geels 2005; Lessig 2009). Or as Monteiro and Hanseth (1996: 326) coin it: "buried deep in 'technical' details [social actors] inscribe anticipations of individual, organisational and inter-organisational behaviour". These technical details are heavily affected by two factors. First, the adoption and actual use of a digital technology (e.g. how is a user using the technology? Is the technology used as intended by its creator or applied in a different context with different intentions and methods?).

Second, the creation phase with a focus on the actual innovators and all influences that determine how the technology functions, including social belief and norm systems. For the latter part, the research identifies several factors that can determine the inner dynamics of technology while at the same time reflect individual, organizational or inter-organizational behaviour.

The insights from legitimacy discourses on these characteristics of technology are therefore not of direct nature but rather show how the friction line of discourses can also dictate technical details. First, the initial purpose of digital technologies is heavily restricted to sectors, which actively promote digitization. For example, as highlighted above, the government sector is suppressing digital technology while banks and insurance companies actively promote its development, which is evident in their role in building the credibility of coding networks. This results in strong financial technology features (FinTech) such as sending, receiving, saving or investing money in digital accounts that follow a clear market oriented and capitalist logic.

Second, platforms that digital products are built on (e.g. Facebook for chatbots, Twilio for short messages such as What's App and SMS or Google for user analytics, geocoding (maps) and advertising integration) actively engage with coding networks to leverage their own strong strategic position in the international digital economy. They finance meetups, offer free online learning resources catered to their own technology stack and invite leading members of coding networks to their regional offices or global headquarters to further connect them to their own plans. This results not only in close personal and financial dependencies but also influences inner technical characteristics of innovations developed by coding networks. Specific technological frameworks that allow general freedom in the development process, but only develop their advantages through their good integration into the existing systems of large companies, are therefore widespread (more details are further discussed in Article II [4.2]). Circling back these trends to the core notion of legitimacy, it is evident that although there is a growing community of "home-grown" digital solutions in Africa, they are largely built on platforms designed and controlled by international networks of either tech-cooperation or affiliated developer networks. Understanding technology's ability to integrate in social systems and thereby

constructing cultural legitimacy must therefore be analysed from a new theoretical angle on scale, which is discussed in the following section 3.

3) Local context and the narrative of local contextual innovations in terms of digital technologies

As already emphasized, coding networks as representation of production environments behind digital technology are on the one hand key players in legitimacy creation but on the other hand do not fit in the notion of a static scalar category such as local, regional, or global with clearly delineated borders and inherent structures. Static scale hereby refers to a container lensed conceptualization that declares space as absolute with clear borders and occupied content. With this line of thought the local for example can be classified as everything that happens within the city of Lusaka, while the municipal border functions as the defined boundary. The discussions above showed how activity in this field can easily cross static scalar borders which is why this conceptualization proves to be difficult in today's wide spanning networks that influence both technical and social structures. Instead, a relational approach to scale highlights the relationships between entities, effectively mapping a dynamic network of interactions that do not necessarily cease to exist when crossing selected space demarcations (Massey 2013, Murray & Overton 2014).

This line of thought also complies with the Multi-Level Perspective transition framework, which highlights the interconnecting mechanisms and influences between the Niche, the Regime and the Landscape. The following discussion therefore first looks at the different repercussions of this relational scale approach in analysing innovation networks. On this basis, the following section then discusses which role local context plays in legitimacy discourses and how the narrative of favouring local contextual innovations persists against the actual process of legitimacy production (derived from the MLP).

Scale as network

Although the stakeholders in coding networks operate and create technology from and for what many scholars would frame as "local" places (e.g. Lusaka in Zambia), a static (and therefore hierarchical) scale order does not allow to capture and properly analyse the

actual influence radius of the network's actors. Hence, it would only offer a limited view on which influences shape social norms and ideas that are part of the technological innovation process. Accordingly, the article starts with two core assumptions: first coding networks produce digital technology and must create legitimacy around it. Second, by analysing technological innovation as a result of network activities, the research focus shifts from the technology and its users to the influences behind its conceptualization, design and production, which can only be analysed through a relative approach towards scale. Therefore, this article conceptualizes the local and the global as opposing sides in the same network (Herod 2003).

"The interconnectivity of scales shifts to the centre of attention and helps in understanding the role of multiscale influences in the production of cultural legitimacy" (Schmitt 2019: 533).

What are the key findings from the empirical data collection referring to this scalar lens? First, the knowledge on techniques and tools, which are necessary to develop digital innovations, is only available in wide-spanning global networks. Traditional education from schools and universities is evaluated as insufficient and outdated, which is why all members of coding networks rely on information from internationally structured networks such as the internet (online tutorials, online courses, or online discussions) or company backed education events (Facebook Developer Circles, Indaba Africa sponsored by Google etc.) (Schmitt 2019). At the same time, these resources separate the innovators "from their own context and cause them to adapt an international narrative of pressing issues, including appropriate tools to tackle them." (Schmitt 2019: 546). This can be observed in particular in the conception of future scenarios for one's own reality of life, which is strongly influenced by digital automation and artificial intelligence. Discussions from other parts of the world are adopted as face value, with the result that many social discourses from Zambia do not find their way into digital technology creation processes.

This condition is further reinforced by the second key finding, the split between individual actors in coding networks. This is illustrated in particular by the different ways in which digital innovators construct their own scale. While most actors merely consume resources passively, a few acquire particular legitimacy through their active interactions

within these international networks (e.g., invitations to visit Facebook's headquarters in the US, participation in hackathons, which also include prize money or attendance at competitive online and offline programs). In the article, they are referred to as scale facilitators because "their own construction of the global contains fewer barriers between the different categories, and pictures it as more accessible and interactable." (Schmitt 2019: 546). This way they translate international structures to the rest of the local coding community while at the same time, through their own actions and reinforcements from within the network, they gain a special position of legitimacy, which they bring back to the local community.

These dynamic in mind leads us to the third and final question, the discussion of which cuts to the background and how the narrative of local contextual innovation persists vis-à-vis the actual process of legitimacy production.

The blind spot of an overly simplified local context

"The emergence of Africa's technology hubs is of crucial importance for those living within the continent, as the trend represents an opportunity for home-grown entrepreneurship devising local solutions to socio-economic problems and propelling Africa's innovation revolution." (De Beer et al. 2016: 240)

When it comes to technologically infused social transformation processes in the Global South, there is a consensus on the need for locally created technology that solves context-specific problems (Unwin 2017). This line of thought originated from the realization that "technology is not neutral" (Polgar 2011: 17) and carries inherent characteristics, which derive from the sociality of involved stakeholder in its production phase. At the same time, this strand argues from a perspective that automatically reduces local actors to strict locally thinking and acting stakeholders. The locality is accordingly rather seen as a fixed social structure that either fits or does not fit to the introduced technology. While this research offers valuable insights into why the implementation of certain digital technologies might have led or leads to societal transformation (either wanted, unwanted or unintended) it tends to not differentiate between different aspects of innovation context. Or, put in another way, it conceptualizes local innovators as a passive social group that exists autonomously from the logic of the objects they create (Jiménez & Zheng

2018, Rey 2009). The embedded values of innovations are therefore not sufficiently considered in the discussion around local context (Zheng 2015) and thus undermine the validity of many studies on sustainable digitization and the understanding of transformation processes.

As highlighted above, it is not sufficient to analyse societal transformation influenced by technology using the traditional static scale concept. Therefore, this research makes use of the MLP, which emphasizes relative, rather than absolute, demarcations between the individual levels. Thus, it becomes clear that the niche does not only exert pressure on the regime level through a technical product, but that sociopolitical structures and practices in the innovation process itself also have an influence on transformation processes.

Thus, from the field of cultural legitimacy that emerges from the concept of MLP, new insights can be gained into local contextuality in the interaction of sociopolitical structures and technologies in the nexus of societal transformation. First, access to different legitimacy sources that are part of the production process but not of the adoption/implementation environment create mismatches between the technology production and the technology implementation. Second, the different impositions of their own radii of action divide the programming community, which is often portrayed as homogeneous, into different parts, each of which has a stronger or weaker influence on the methods used to develop digital technologies. In summary, these findings suggest that what is declared to be the solution for more conflict-free and thus more successful transformation processes to the local context must be considered in a more differentiated way.

In sum, by linking the cultural legitimacy of the production process to the question of scale, the article focuses on the networks behind new technologies and how they construct and practice scale beyond a static local, national, and global framework, which in turn opens up a new discussion of how narrow contextual digital technologies can actually be.

4.1.3. Article I

Schmitt, D. (2019). Production Environments of Digital Innovations: A Scalar Perspective on Cultural Legitimacy in Zambian Coding Networks. *Perspectives on Global Development and Technology*, *18*(5-6), 527-552. DOI: https://doi.org/10.1163/15691497-12341531

4.2 Article II — Influences and the production environment of technology in the Global South

Title: "Influence in online spaces: mapping Twitter networks of innovation hubs"

4.2.1 Background

Ever since socio-technical theories such as the Multi-Level Perspective gained substantial momentum for analysing and explaining ongoing transition dynamics in the Global South, scholars have pointed out the usefulness of conceptualizing upcoming spaces of change as niches (Wieczorek 2018). In this context, niches are understood as an environment that provides protection from the influence of dominant social structures (Kemp et al. 1998, Geels 2011). The majority of empirical studies conducted in the development context resort to Strategic Niche Management case studies, that explore and determine the "strategic navigation of the process of niche formation" (Wieczorek 2018: 204). The major driver behind this being the idea of "bringing together [niche] actors and their activities in such a way that together, they can accelerate the change towards sustainability" (Wiecszorek 2018: 204).

Simultaneously, the emergence of digital technologies in the development context and its effects on societal transformation processes and shifts in power dynamics sparked interest from the more established development studies side. Especially the Information and Communication Technology for Development (ICT4D) community has a long history in research on new technical innovations and its development effects. With digital technology on the rise, they have established frameworks of understanding new digital innovations as platforms that monopolize the potential to facilitate between the majority of previously decoupled development goals (Bukht & Heeks 2017). Based on Tiwana et al (2010: 676), Ghazawneh and Henfridsson (2015: 199) define digital platforms as "software-based external platforms consisting of the extensible codebase of a software-based system that provides core functionality shared by the modules that interoperate with it and the interfaces through which they interoperate''. The difference to previous conceptual outlooks on digital technology therefore consists of a platform's ability to function as

podium on which new modules can be built upon. Information and communication technology for development is therefore assigned a new role away from a single target tool with specific purpose to a comprehensive platform, which is conceptualized as base that new technologies can interoperate with (Heeks 2018). Whereas this new conceptual approach tackles recent technology designs and capabilities, there are contemporary questions concerning its interplay with some of development research most basic groundwork. Especially its interaction with the notion of context specific solutions to tackle sustainability challenges emerges as key new problem statement. As many scholars from the ICT4D field have pointed out, the key to successful implementation of technology lies with its contextual applicability and its deep-seated embeddedness in local structures (Bhadauria et al. 2018, Bailey & Osei-Bryson 2018, Matuschewski 2006, McQuail 2007 Unwin 2017). With platforms providing the substructure for further technical applications, it becomes necessary to have a deeper look into understanding how they work, why they evolve in their specific context and which platforms are used over others.

The research conducted for this article starts by combing the two above mentioned trends, one being the conceptualization of innovation spaces in the Global South as niches, the other one being the conceptualization of information and communication technologies as platforms. First, three innovation hubs from Zambia, Uganda and Ghana represent niche structures and constitute the research objective and are therefore analysed based on their inner dynamics. Digital technology in Africa is largely associated with tech hubs that are steadily becoming a constant institution in business environments across the continent. In 2019 their number in Africa grew to 618 with congested areas in Kenya, Nairobi, Egypt and South Africa (Giuliani & Ajadi 2019). They are characterized by open workspaces, acting as facilitator for the country's or local digital ecosystem and create environments for mostly young catalysts and professionals who advance technological agendas (Jiménez & Zheng 2018). The core mission statement of such hubs often evolves around digital entrepreneurship and the promotion of new technology to champion the next step after the fast quantitative growth of information and communication technologies in the past 20 years (Jiménez 2019). For the conducted analysis in the article, this development especially demonstrates that there is a growing community engaged in building digital technologies from within their countries to create home-made solutions which as

discussed above are widely seen as superior to imported and contextually distant ICT projects.

The second trend of incorporating platforms is utilized by looking at the influence connection between stakeholders within and beyond African tech hubs. As platforms provide technological capabilities that other innovations can be built on, one of the core questions of this article is on how innovation hub actors spread and receive information on new platform technologies and problems they perceive as worth solving. Platforms are therefore understood as toolboxes that stakeholders can choose to create their own innovation from. Considering technological advancement and the wide accessibility due to open-source projects and business interest of platform companies and provider, it is interesting to understand why and how different actors choose one platform toolset over the other. For example, during the last years, we could see a strong movement towards Unstructured Supplementary Service Data (USSD) code for agricultural information systems in Africa (Akinpelumi 2019, Abbott et al. 2021). In this example, USSD is a technology that can be conceptualized as platform on which other services such as weather information systems or market price instruction applications can be built on. It is provided by telecommunication companies and is accessible through every GSM mobile net. Another example is the growth of Facebook Chat Bots that integrate within Facebooks API and provide automated communication tools for business, NGO and government Facebook pages. Here, Facebook and its incorporated API tools are used to create customized communication bots that automatically answer customers, citizens, or private persons without the need of manual labour in the background. In this context, the article approaches innovation hubs and its stakeholders from a network perspective to better understand how new ideas around technologies are discussed and how various network nodes possess the power to steer discussions in specific directions. The focus lies on influences within these networks and how different actors are connected and share their information amongst each other. The results of this analysis in return give valuable information on why specific platforms are used and which stakeholders are most involved in setting the agenda for technological developments.

Not only because it is a technological platform itself, but the data for the empirical analysis is also gathered from Twitter, a social media platform that is used to discuss ideas or connect to other peers. The data set consists of 97040 individual Tweets that are all connected to one or more of the three inspected innovation hubs in Zambia, Ghana and Uganda. The used social network approach "map[s] and measure[s] formal and informal relationships to understand what facilitates or impedes the knowledge flows that bind interacting units" (Serrat 2017: 1). The methodology of this article therefore aligns with the conceptual focus on networks and influence factors and introduces an innovative way to analyse structural relationships within technology's production processes.

4.2.2 Integration

Against the backdrop of the outlined arguments on societal transformation, the following integration section discusses the article's results through the lens of production environments and network activities.

First, I will argue that the production environment is a valuable categorial unit for technologically influenced transformation that is neglected in favour of implementation analyses. I will do so by discussing how sustainability transformation offers a fitting approach of conceptualizing innovation hubs as niches that explain the importance of grasping where innovations in the context of societal transformation dynamics derive from. Second, I will discuss the particular network approach used in the article and its utilization to analyse influences in innovation spaces, including its connection to the first argument of niches and transformation processes. Third, I will elaborate on the empirical outcomes of the study and show how different stakeholders use their position in the network to steer discussions and enable different layers of access to information that are relevant for the direct development of technical products.

1) Innovation hubs as niches

Innovation hubs are integral parts of ongoing digital innovation efforts in Africa. They are characterized as physical or communal spaces and gather a large variety of stakeholders from technology enthusiast to seasoned entrepreneurs.

"The general discourse around innovation hubs is broadly optimistic, with hubs largely being theorized by their potential output—the ability to drive economic growth in Africa by linking motivated entrepreneurs with the business skills, technology and networks that they need to thrive. However, similar to the start-ups they support, tech hubs can also be fragile as empirically observable by the 150 hubs that ceased operations between 2016 and 2018. This tension between tech hubs holding vast economic potential, yet being vulnerable to closure, has contributed to research focused on the sustainability of tech hubs." (Schmitt & Muyoya 2020: 3)

I argue that this fragility paired with the protectionism of a relatively homogeneous technology affine community classifies innovation hubs as niche environments in the broader scope of the Multi-Level Perspective. Niches are defined by their sheltering function from regulatory influences and other market and social dynamics as well as their dependency from landscape developments that open opportunities for transformation mechanisms (Shot & Geels 2008). The sheltering is hereby provided by the network of likeminded peers, an international technology community and role models in form of famous entrepreneurs or successful digital companies, while the landscape developments are trends in digitalization, the growing accessibility of information and communication technology in form of mobile phones and internet access and the strong pressure to utilize digital technologies to reach higher levels of efficiencies (e.g. see Ochoa 2022). Furthermore, in the context of efficiency gains and the pressure to adapt to new technological vanguards, proceedings in and from niche environments stand in fierce competition with established practices that can be defined as regime. This holds especially true when focusing on developments in the Global South, a context that is defined by its diversity between indigenous, western and hybrid structures that are invariably contesting each other (Francis et al. 2020). Competitive relationships between already established practices and new digital innovations can be witnessed in a large variety of social structures such as changes in communication patterns due to mobile phones (Contarello et al. 2007), the need to utilize drones to establish new transportation and logistics opportunities in the health care sector (Nyaaba & Ayamga 2021), or in agriculture, where more and more farmers rely on digital information systems for reliable market price information (Evans 2018). For the emergence of these technical frontier

applications, innovation hubs play a key role. Not because the organization behind a hub actively creates technology but they instead primarily "exist to enable and support entrepreneurship and innovation" (De Beer et al. 2016: 243). The hereby created ecosystem is in return characterized by its clear delineated borders between support and opposition and between disruptive and established practices that are also key characteristics of niches within the MLP framework.

Besides these internal dynamics of innovation hubs, the above-described network formation of stakeholders with the goal of producing and enabling new technology also shows the importance of analysing innovation processes within their production environment, instead of just looking at individual social actors or institutions. Based on the point that "technology is not neutral" (Polgar 2011: 17) and that it carries inherent properties that arise from the sociality of the actors involved in its production, both social structures and technological properties are limited for understanding transformation processes when studied separately. Therefore, innovation hubs as the social networks around technology's production have significant impact on how technology is shaped, and which social structures are transferred during the initial production phase. Below in the empirical data part of this chapter, we can see those frameworks and languages such as Python, that amongst other applications is used for machine learning (especially for data science purposes), are advertised through these network settings and serve as great examples on how different actors influence the production environment. In this case, for a machine learning model to work, it needs normatively evaluated tagged, annotated or classified data, e.g. for credit scores (income, expenditures, social network, living area etc.) or justice systems (previous convictions based on characteristics such as age, sex, family relationships etc.). Therefore, the social bias of the production background is transferred into the technology itself, which makes it an important piece in understanding technology's influence in transformation processes (for further details see 3).

2) Analysing niches through social media data and influence in innovation hub networks

The selected innovation hubs investigated in the article are the BongoHive Hub in Lusaka (Zambia), the Innovation Village Hub in Kampala (Uganda) and the iSpace Hub in Accra (Ghana). These hubs were selected with the help of AfriLabs as three representative case

studies from Southern, East and West Africa. As the data analysis not only considers the connections within but also between these hubs, the applied niche concept does not deal with isolated innovation spaces but rather acknowledges their interdependencies between each other and recognizes the network structure within this inter-regional innovation community. Niches should therefore not be understood as locally isolated spaces, especially when looking at niches dealing with internet and digital innovations that in their own nature are highly dynamic and intertwined. Understanding these interweavements can be a very time consuming and complex research task when approaching it from a classic qualitative methodological perspective. One does not only need to first get a basic understanding of all involved stakeholders in such convoluted networks but also find out each stakeholder's activity as well as their radius of influence. However, a novel, more sophisticated approach to research in these settings is to work with already existing social media data. Not only because actors in innovation hubs are mostly young and experimental and therefore prone to using online communication tools, but also because the digital trail they leave contains a large amount of hidden information on how these interregional networks function and what content is created and spread there (Java et al. 2007).

"For our case study, we, therefore, mined Twitter data (97,040 tweets) that cover the whole Twitter activity around the selected hubs for a duration of three years (time frame: 15 May 2016 00:03:00–14 May 2019 23:30:00). We asked what networks these hubs are part of and how we can uncover and analyse influences within the networks." (Schmitt & Muyoya 2020: 2)

From a conceptual point of view, the influence of different stakeholders within these networks is analysed through their activity that is measured by three parameter values: first the activity in form of creating talking points (creating new tweets), second in form of engaging in direct discussions through replying to other stakeholders and third through their endorsement of other statements through retweeting. These three parameters in return assign each stakeholder a unique position within the network that is then used to determine what level of influence each stakeholder holds and how it is used.

3) Empirical outcome: the influences behind technical innovation paths

The analysis in this chapter is based on data that is in depth presented in the article Schmitt, D., & Muyoya, C. (2020). Influence in Technological Innovation Spaces: A Network Science Approach to Understand Innovation for Sustainability in the Global South. Sustainability, 12(5), 1858". The research was conducted aiming at understanding how influence within innovation hubs in Africa is created and which stakeholders use their position to influence the talking points by steering discussions on technical and social aspects of platforms in certain desired directions. The empirical analysis is hereby split into two major sections. First, the section that deals with the actual information by stakeholders and the content of their messages (tweets). Second, the article elaborates on relative network connections of those stakeholders.

First insights were gained by looking at hashtags and most frequent terms within tweets. Hashtags make it possible for users to make their message searchable and therefore create visibility outside of their direct account's network. The most used hashtags are structured into several categories that offered first insights into how the niche environments in form of innovation hubs are structured and what content circulates within this community. Stakeholders of hubs possess strong ties to first and foremost their country but secondary to the whole African continent. This constitutes in the finding that more than 6% of the analysed content produced online contain either the terms "Ghana", "Zambia", "Uganda" or "Africa". This supports the claim that innovation hubs are built around an identity that links them to local problem solving and the desire for contextual solutions within their own country or continent, which is also a major objective of niches in transformation processes (Smith & Raven 2012). A second pattern derived from the data is a keen focus on learning through either events or online resources, indicating the shared goal of education and knowledge sharing. In combination with talking points about campaigns on "hot topics" of the innovation space that are mainly initiated by international programs, these patterns show how the hub's network is utilized as a way of improving through either education or discussions with other peers, who work in a similar innovation field. This matches typical niche dynamics where the involved stakeholders try to create a supporting network that shields innovations from outside influences while simultaneously preparing them for openings in the regime level and therefore wider acceptance (Shot & Geels 2008).

As a next step the article builds on these learning and educational connections and focused on the information flow of content and on the stakeholders most active and influential in diverting and sharing knowledge resources. First, the article showcases the connections within each of the three investigated hubs. By looking at direct connections between each node in the network it is evident that the majority of all stakeholders in the innovation niche have clear alliances to one of the three hubs, more specifically to the hub in their referred to respected country. As Friederici (2016) pointed out, innovation hubs assemble previously distant innovation actors and redefine opportunities for them. With the data from the article, this argument can be clearly validated. Beyond this, the next argument derived from the data elaborated with respect to central actors in the network that function as bridges between these delimited three innovation hubs. They are defined as either umbrella groups that hold strong ties to a variety of innovation hubs, or as individuals who possess interregional and international influence and are therefore known and active in several different communities.

We can now see that the assembly process [of innovation hubs] does not only connect local actors to a locally bound innovation network but additionally links them to global network structures that are introduced and translated by key community facilitators, which actively shape ample and far-reaching global structures." (Schmitt & Muyoya 2020: 13)

With methods from network science the analysis in the article then showcases what implications these key community facilitators mean for the circulation of innovation. First, the intermediaries between communities are predominantly financially and ideologically influenced by actors who are connected to the sustainable development agenda of the United Nations (SDGs). This results in a large stake of platforms being developed around topics such as gender and financial inclusion or adaptation tools for climate change. Second, the modality of developing new platforms is steered towards start-up philosophies that include flexible co-working arrangement and loose hierarchical structures, which stand in fierce opposition to traditional top-down business organization. Even the technical tools advertised for digital innovations within these niches are highly influenced by the facilitators. Examples here range from the promotion

of Python for data science projects to the introduction of trends in programming frameworks such as Node.JS or React.JS. The same also applies to business models and market access strategies that are added by financial investors and networks and include a strong focus on venture capital and its desire to quickly "conquer" specifically targeted market segments. Concluding, this dynamic within and between geographically distant hubs offers a detailed view on how information on technology, advertisement of new trends and weighting of necessity of problems circulates in the innovation niche and which role influential stakeholders with their sizeable communication and action radiuses play.

Circling back to this dissertation's initial inquiry on societal transformation under the scope of technological innovation the article offers a number of relevant findings. Looking back at how linkages between social and technical arrangements form firm structures that in return provide frameworks for fulfilling societal functions, the article clearly demonstrates how specific social actors determine the direction of technical developments. In combination with powerful protecting mechanisms created by the relatively homogeneous technology affine community, this niche is on the one hand an opportunity for innovative ideas that might otherwise be drowned by regime formations, on the other hand it demonstrates how isolation benefits the evolution of powerful positions that are occupied by special stakeholders in the innovation hub network. Given that technology carries specific social structures, for transition phases from one socio-technical system to an emerging one from the niche, these facilitators possess overproportioned power they can use to not only filter information but also to normatively weigh the importance and contents of discussion points.

As for transformation dynamics within the framework of socio-technical systems, from a different angle this article's empirical enquiry supports the findings from Schmitt (2019), which was elaborated above in the chapter on cultural legitimacy. Like Hughes (1983) pointed out, the social environment for an implemented technological system must be suitable or it runs into danger of lacking widespread adoption. Hence, from a reverse point of view, social structures are also able to change due to implemented technology, as can be seen on recent events e.g. around social media and election behaviour (Schneble et

al. 2018). Analysing transformation processes from an emergent perspective (Feola 2015) then requires understanding not how technology changes social structures during or after its implementation but rather in which direction this societal transformation takes place. In the same way the study on cultural legitimacy highlighted the disconnection between the stakeholders behind new technologies and their direct cultural surroundings, the empirical data from this article show where this disconnect comes from and how it manifests itself in the use of certain organizational, technical, or educational structures.

4.2.3. Article II

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Article

Influence in Technological Innovation Spaces: A Network Science Approach to Understand Innovation for Sustainability in the Global South

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Abstract: The number of scholars working on transition concepts in the Global South is rapidly increasing. In this context, a substantial amount of research output particularly focusses on niches and how they affect transition towards sustainability in a wider framework of the multi-level-perspective. At the same time, there is a growing interest in digital technology and its effect on sustainability challenges. In this article, we combine the two fields, and by utilizing social media data, we create an innovative network science approach to analyze the production environment of digital innovations in Africa. We focus on three innovation hubs that we conceptualize as niches and innovation intermediaries that not only create communities to develop, test and implement new technology but also function as networks to discuss and form new ideas around innovations. Our key findings show how local communities are embedded in larger innovation structures. The connections between local stakeholders and global actors are predominantly created through bridge actors, who hold key positions in their communities. With tools from network science, we demonstrate that these linking elements can regulate and steer discussions and therefore, strongly influence digital niche environments. Utilizing geographical location data, we can also see that the online space of technological innovations in Africa is heavily cantered in urban areas.

Keywords: Twitter research; influence analysis; sustainability; transition; network science; innovation; tech hubs; Africa; ICT4D

1. Introduction

With the establishment of sustainability as a key goal for global development, we see a growing integration of core transition concepts for research on socio-technical systems in the Global South (Due to the complexity of societal structures, the term Global South is used to emphasize power relations and inequalities within the research context rather than using simplified and normative terms, such as "developing countries" or "third world countries"). For system changes towards sustainability to be effective, research from transition studies implies that interlinkages between institutions, socio-cultural systems, the economy and technology are important to understand and govern such transformations [1,2]. As Wieczorek [3] pointed out, transition research in the Global South is highly influenced by strategic niche management approaches (SNM) and the multi-level-perspective (MLP) [3,4]. Within the MLP framework, niches are characterized by the provision of protection from the dominant market and societal dynamics, therefore, enabling and fostering new radical innovations [5,6]. The focus on niche environments comes as no surprise as it not only builds on established major research from transition scholars in western hemispheres but also applies to dynamic and fast-changing societal settings that are prevalent in the Global South. Most of this conducted

research on niches in the Global South deals with a variety of topics of which energy, agriculture and mobility are the most dominant ones [3]. At the same time, there has also been a growing interest in the digital economy and its associated information and communication technologies (ICT). El Bilal and Allahyari [7], for example, looked at agriculture food chains and integrated ICT's contributions to sustainability outcomes. Another example can be found in research on sustainability transition and the impact of the sharing economy fueled by digital innovations [8,9]. Simultaneously, a large margin of technological developments in sustainability sectors also stem from new ICTs or are influenced by important digital innovations that enabled stakeholders to develop new sustainability models. Examples of this can be found in smart city research that builds on data connectedness and the Internet of Things (IoT) [10] or transition perspectives in new energy systems, such as smart grids [11].

In the Global South, and especially in Africa, digital technology is often associated with tech and innovation hubs that have emerged as niche actors with the mission to solve economic, social and ecological problems with the tools of digital entrepreneurship and innovative business ideas [12]. Their number on the African continent has grown to 618 in 2019, which is an increase of 39.8% to the 442 in 2018 [13]. The growing attention and rapid expansion of innovation spaces not only show the dynamic behind digital technologies but also highlight the high expectations for development processes, including pathways towards sustainable development. These new developments also demonstrate that digital technologies are no longer only imported but innovation hubs establish local development environments to create home-made and context-specific solutions [14]. But as much as many countries in Africa leapfrogged their way to wide accessibility and use of ICTs, comprehensive digitalization is still rare, and many niche actors have trouble to upscale and establish their technologies [15]. And although the quantity of those hubs is constantly increasing, its impacts and actual outputs are highly debated, asking for more in-depth research in this field [16–19].

In a more and more digitalized world, these processes clearly demonstrate two trends: First, the growing importance of understanding local born digital innovations for sustainability research in Africa. Second, digital technologies from and for Africa are often connected to innovation hubs that create niche environments for new technologies. With the rise of sustainability research that builds on digital technology, we want to contribute to this ongoing debate by exploring niche actors around innovation hubs and their networks that convoy innovation processes in Africa. Understanding the development and production environment in the form of those hubs is, therefore, of key importance to discern where new ideas and practices for sustainability models that encompass digital elements stem from.

We investigated those digital innovation networks by looking at the online activities around three different innovation hubs in Africa, namely the BongoHive Hub in Lusaka (Zambia), the Innovation Village Hub in Kampala (Uganda) and the iSpace Hub in Accra (Ghana). We selected these hubs with the help of AfriLabs as three representative case studies from Southern, East and West Africa. AfriLabs is a network organization that connects all major innovation centers from across the whole African continent and organizes reoccurring conferences amongst key leaders in digital innovation communities. Because we wanted to understand the context of innovation places that contribute to and influence digital development processes, we utilized methods from social network analysis (SNA). As people tend to cluster in groups "as a result of interaction opportunities defined by places where people meet" [20] (p. 529) and these groups are important in the establishment of similar views amongst all members [20], SNA offers us a suitable framework for our methodological approach. We followed a tradition of several case studies that already connected SNA to innovation studies (e.g., [21,22]), proving its unique value within the innovation context. In recent years, there has also been a growing interest in utilizing social media networks, as online interactions provide new data for the formation of communication structures and the formation of views and opinions [23]. For our case study, we, therefore, mined Twitter data (97,040 tweets) that cover the whole Twitter activity around the selected hubs for a duration of three years (time frame: 15 May 2016 00:03:00–14 May 2019 23:30:00). We asked what networks these hubs are part of and how we can uncover and analyze

influences within the networks. We, therefore, used a spatial and scalar perspective on the online space of digital networks and contribute to a better understanding of innovation hubs in Africa. Thus, this article adds two valuable insights to sustainability research: First, it introduces an innovative way of dealing with large social media data to analyze and understand its influence in niche environments. Second, it contributes to current discussions on digital innovations for sustainability research in Africa.

The structure of this article is as follows: First, we give an overview of innovation spaces in Africa and linked research to those technology hubs before we discuss our spatial and scalar approach to network research. We conclude the theory part by summarizing the fundamentals of network science before briefly highlighting Twitter research and the relevance of our approach to transition research on socio-technical systems. Before we present the data and end with a discussion of our results, we also elaborate on our methods, including giving an access-to-all code.

2. Innovation Hubs in Africa

Innovation hubs are physical and communal spaces where technology and entrepreneurship enthusiasts gather to obtain and share knowledge, skills and resources that are often used to develop ideas and build businesses [18]. Tech hubs employ hybrid income generation models that include public and private partnerships, paid co-working space, consulting services and paid skills development. They also consolidate their efforts by building on national, regional and continental peer learning networks [24]. The last decade has seen the emergence and rapid growth of technology hubs across Africa. This growth has been linked to three key factors: improved ecosystems and operating environments that attract and support technology advancement, increased volume of venture funding raised by tech startups and pre-existing hubs re-working their business models to better suit their markets [25].

The general discourse around innovation hubs is broadly optimistic, with hubs largely being theorized by their potential output—the ability to drive economic growth in Africa by linking motivated entrepreneurs with the business skills, technology and networks that they need to thrive [26,27]. However, similar to the startups they support, tech hubs can also be fragile as empirically observable by the 150 hubs that ceased operations between 2016 and 2018 [24]. This tension between tech hubs holding vast economic potential, yet being vulnerable to closure, has contributed to research focused on the sustainability of tech hubs [28,29]. Research has also underscored the importance of analyzing hubs beyond economic inputs and outputs by understanding their impact on aspects of human development, such as wellbeing and agency [12]. More recently, there has been an increased emphasis on understanding the processes, underlying ideologies and value systems within tech hubs and the contexts they operate in [30,31]. From an innovation perspective, Friederici [17] used the concept of innovation intermediation to consider both the process and outcome of tech hubs. This approach provides a framework to analyze how technology hubs serve as intermediaries between entrepreneurs and enabling actors (such as corporates and investors), and in doing so, change the underlying social structures in ways that shift economic opportunities that technology entrepreneurs can access [16]. In the discussion of our data, we adopted this approach and used its underlying stakeholder network logic to understand different stakeholders' positions in this complex system structure.

3. Spatial and Scalar Network Approach

From a theoretical perspective, there has been an increased interest in spatial and scalar dimensions of innovation processes. Notably, after Lawhon and Murphy [32] suggested broader research agendas for the field and Hansen and Coenen [33], Bridge et al. [34] and Truffer and Coenen [35] collected, sorted and analyzed conceptual frameworks for geographical aspects of innovation, a large variety of space and scale concepts have been used for a growing number of empirical research. In this regard, several clusters inspired by human geography have emerged. They range from evolutionary economic geography, conceptualising space as geographical dissemination of routines [36] or relational perspectives of political economy in energy transition [37] to place-making approaches that emphasize

political process and their influence over the progression of socio-technical systems [38]. Following the concept of innovation intermediation, we approached our research from this relational perspective and defined space as a relation between objects [39]. In our case, this translated to different individual and institutionalized actors who connect through online tools and form a relational network. In the same sense, we did not define scale as real material existence but instead see it as a fluid process that is "a way of framing our understanding of the world" [40] (p. 229). As a result of network research, scale, therefore, does not consist of static analytical categories that can be clearly delineated. Scale, rather, emphasizes that the local and the global are both part of the same network and have no hierarchical order [41]. Consequently, instead of analysing relations through static categories, the interconnectivity of scale shifts to the center of attention.

Concluding our practical and theoretical context, we identified four above mentioned trends that can be summarized as follows: First, transition scholars are more and more interested in understanding sustainability transformations in the Global South [1]. Second, digital technologies fueled by rapid developments and diffusion of ICTs have brought up the question of what role digital technology plays as a driver behind sustainability transitions in the Global South [2,3]. Third, in Africa, actors in the field of digital innovations are often linked to institutionalized innovation hubs that, therefore, play a key role in the innovation process of digital technologies [16,17]. Fourth, understanding spatial and scalar dynamics has proven to add valuable insights into innovation processes. Innovation hubs are embedded in complex global networks that influence how digital innovations are shaped [42]. The structure of those hubs can be constructed as innovation intermediaries, which helps in understanding the internal dynamics of hubs through a relational space and scale conceptualization.

In this paper, we, therefore, analyzed three innovations hubs in Africa, namely BongoHive (Zambia), Innovation Village (Uganda) and iSpace (Ghana). By looking at their Twitter activity and associated networks, we aimed to uncover some key drivers behind digital innovations in Africa and what influence networks exist around those highly active innovation spaces. We focused on the questions of what the production environments of digital innovations in Africa look like and what position and influence actors in the (niche) production of digital technologies occupy, create and use. By doing so, we want to encourage further network research around digital technology and its production environment in Africa as digital innovations play an increasingly important role in many topics of transformation research. Additionally, this network approach to online spaces and niche research can also be used in other contexts and introduces new methodological perspectives for sustainability science.

4. Methods

Twitter is a social media platform that enables users to distribute short messages (so-called tweets) that contain up to 280 characters (Twitter changed the character limit from 140 to 280 in 2017), in addition to an optional media file, such as a GIF, a video or a picture. What distinguishes Twitter from other online communication tools is the very specific code-enabled practice behind each tweet. Schmidt [43] (p. 5) described this code between social ties and lingual references as a way to "structure the flow of communication and to filter information". The fundament for communication on Twitter is based on three basic concepts. First, each account can follow other accounts and see their tweets on its own timeline. This way each account creates a network of following and followed accounts that determine the composition of the account's timeline (start page). Second, there are three different ways of communicating with Twitter: creating a new tweet, replying to an existing tweet and retweeting a tweet (and therefore, forwarding a tweet to its own audience). Third, with the use of a hashtag (#) that is followed by a term or phrase, it is possible to make your message searchable by the platform and therefore, enable visibility outside the initial account's network. In a similar way, the @-sign allows the tagging of other accounts and is used to reply or address another account.

Research with and about Twitter is constantly growing. Especially after Weller et al. [44] collected and organized fundamental concepts of the digital platform for social research purposes, many research

fields have experimented with the use of Twitter data (see [45–47]). Understanding how actors use the online space to connect and communicate in combination with a specific topic, such as disaster risk [48], tourism [49] or supply chain practice [50], has been the central drive behind this move. From an abstract point of view, this comes as no surprise as Twitter activity creates a social network between a variety of actors and institutions. Social network analysis approaches concentrate on these created connections and "map and measure formal and informal relationships to understand what facilitates or impedes the knowledge flows that bind interacting units" [51] (p. 1). Due to its constant growth in user bases to ~330 million in 2019, tapping into these large datasets and uncovering dynamics in complex social systems can be a valuable addition to more established research methods.

As Bruns and Moe [52] elaborated, Twitter can be used for a large variety of communication types. Following their categorization of communication types, we mainly find communication-based on hashtags that encircle the discussions on the three innovation hubs from a macro perspective. Here the audience of tweets is specifically bound to a hashtag that has the potential of carrying the message outside of one's own follower sphere and therefore, can be described as a public statement. In our dataset, we generally saw hashtag-based exchanges but acknowledge that some of the tweets also have a small-scale reach with no use of hashtags and only circle within a specific account's followership. For our network analysis, we filtered out some of those exchanges to create better visualization for the core connections and therefore, ignored isolated communities.

Besides using most common terms, bigrams, most active users and other basic metadata that we predominantly extracted from the tweet's text, in this study, we utilized the Twitter data with methods from network science. According to Kenett and Havlin [53], network science is one of the most active fields in interdisciplinary research and shows that connections between different entities in complex systems can be analyzed by not only looking at the entity itself but also at their position and connection within a network [54]. Network science works with the connections between entities and focuses on the structures and relations between nodes [55]. In network science, a node is a representation of an entity that stores data. Nodes are connected to each other via edges that, therefore, function as a link between nodes and can also store additional data in the form of weight [56]. In our case study, each node was a representation of one Twitter account that actively participated in the form of writing or retweeting information about one or more of the selected innovation hubs. Edges show in which ways those accounts replied, retweeted or mentioned other accounts and vice versa.

Data Characteristics, Preparation and Processing

Our whole code for downloading and processing the data can be accessed on Github (https://github.com/DanSchmitt/Influence-in-online-spaces-Mapping-Twitter-networks-of-innovation-hubs). To better understand the production environments of digital innovations in Africa and analyze the position and influence that actors in the (niche) production of digital technologies occupy, create and use, we downloaded all tweets that contain the name of at least one of the three targeted hubs. This included hashtags about the hubs, replies to a discussion about a hub and retweets that talked about at least one of the hubs. For the download, we accessed Twitter's application programming interface (API) through the Full-archive endpoint via a Python-based library called Tweepy. The time frame was set to 15 May 2016–14 May 2019, covering 3 years of Twitter data about our selected case study. With these settings, we captured the first tweet on the 15th of May 2016 at 00:03 h and the last tweet on the 14th of May 2019 at 23:30 h with 14,665 total unique users and 97,040 individual tweets.

The tweets are stored in JavaScript Object Notation (JSON) format. JSON is built on a collection of name and value pairs, with attributes and associated values. Each object (tweet or user) encapsulates attributes that contain information about the object. These attributes range from unique user ID to timestamps, follower counts, geodata, language or messages (tweet text) and many more. Due to restrictions from Twitter's privacy terms and conditions, we are not allowed to publish our data, but a sample of the tweets' metadata structure can also be found on our Github.

As a way of extracting relevant information, we approached the Twitter dataset from two different angles. First, we analyzed fundamental quantities. Those are total tweet count, language used in tweets, unique users, average number of posts per user, most active users, unique hashtags used and the most used hashtags. We chose to extract this information to get a good overview of our dataset and determine the most active users in comparison to average users and most discussed topics through hashtag analysis. As a second step, we extracted the text from tweets and analyzed the most used terms and most used bigrams by using techniques and tools from Natural Language Processing [57]. A bigram is a string of two adjacent words and demonstrates which two words were most often used together. We further analyzed co-occurrence of terms in full tweets that in contrast to bigrams do not have to be in a sequence but could also be segregated by other words in the same Tweet. The information provided by this method also helped us in understanding broad topics and content of messages.

For us to understand the regional origin of tweets and how influence in online spaces is connected to geographical areas, we created a heat map for the activity on the African continent. Out of the 14,665 total unique users, 12,312 tweeted with geodata, including the voluntary location information in the profile information. Two hundred and eighty-six (2.32294%) locations resulted in an error due to unclear information for Google maps API, e.g., "Pearl of Africa". For the heatmap, we utilized tools from Google fusion tables using the number of Twitter accounts with no weighting on individual tweet numbers.

To get a better understanding of the network structures within our dataset, we used a variety of algorithms. For layout purposes of all three graphs, we used the ForceAtlas2 method that is a generic way of spatializing data [58]. For our mention network visualization, we used the modularity algorithm to detect communities within our network [59]. The modularity of the network part is calculated as a value between −1 and 1 "that measures the density of links inside communities as compared to links between communities" [60] (p. 2). This method provided us with a better understanding of the digital communities that are formed on Twitter and highlights the interconnectivity between them. For our replies' network visualization, we used the betweenness centrality algorithm by Brandes [61] to find the shortest paths between nodes that in return, provides a useful measurement of centrality within a network. As discussed in-depth by Riquelme and González-Cantergiani [62], centrality in Twitter networks explains the position of accounts that determines control over information flow within the network. This method in combination with further knowledge of the account itself, enables us to understand the significance of the account when it comes to its range of influence, its coverage and its control over online discussions. In connection to tweets that are replies to other tweets, this method gives us a good understanding of whose discussion inputs are central in the network and who can regulate and steer certain talking points due to this power [63]

Visualization of the networks and the above-elaborated algorithms was done in Gephi. Gephi is a network analysis and visualization software that was introduced by Bastian et al. [64] and is used in a variety of scientific fields, such as biology (see, e.g., [65]), media studies (see, e.g., [66]), or economics [67]. We used Gephi to create an easy to understand visualization of connections between different Twitter accounts, including intensity, cross-linkages and position within the whole network.

Of course, there are some limitations to this case study and the involved methods that we want to address before presenting the results. First, we cannot assume that all relevant stakeholders of the inspected innovation networks are regular Twitter users and put effort into participating in online discussions around their work. Because of this, we compared and discussed our outcomes with experts from the three African innovation hubs and made sure to have a good representation of active stakeholders in our data before conducting the actual analysis. Second, we chose three innovation hubs with the support of AfriLabs that represent Southern, Eastern and Western Africa. Although we were very careful to find good case study examples, some hub's innovation communities are quantitively larger than others and therefore, had a larger representation in the data set. The final limitation is concerned with the Tweets' content. In our base analysis, we were only able to analyze alphabetical

characters, numerical characters and emojis. Therefore, our study did not factor in any content in the form of posted pictures or videos.

5. Results

As briefly mentioned above, the results are structured into two sections. The first one is based around fundamental metrics of the dataset, while the second one focuses on network analysis and understanding relationships within the online space of the three inspected innovation hubs.

The dataset contains a total of 97,040 Tweets with the first Tweet posted on the 15th of May 2016 at 00:03 h and the last Tweet posted on the 14th of May 2019 at 23:30 h. Of the collected tweets, 95.88% (93042) were in English.

5.1. User Metrics

While the average account posted 6.62 Tweets during these three years, Figure 1 illustrates the detailed distribution of the tweets in connection to the 14,665 unique users in the form of a histogram. With most users (between 10^1–10^4) only tweeting between 1 and 100 times, we can see that the large majority of tweets come from a wide Twitter user base. In contrast, the top 10 most active accounts made up for 14.98% of all tweets, while they only represent 0.07% of the total user base. This highlights two types of users: 1) users who only casually participate in the active shaping of online discussions and exchange of ideas (<100 tweets in 3 years), 2) users who are very dominant and visible in the online space of the three innovation hubs (>100 tweets in 3 years).

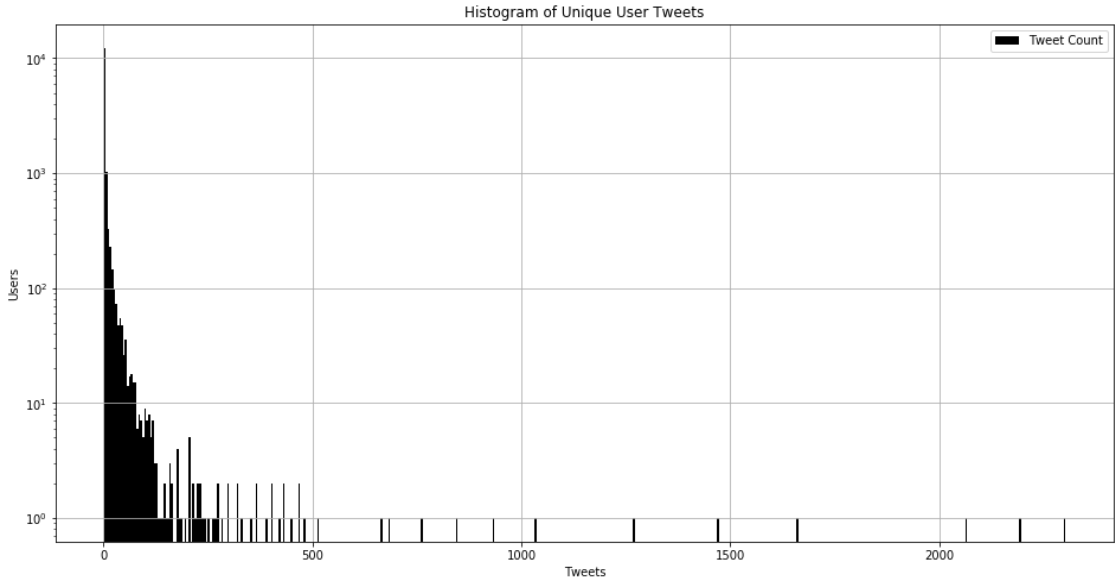

Figure 1. Histogram of unique user Tweets.

Considering these few user accounts for such a large percentage of all tweets, it is worth looking at them in more detail. Table 1 gives an overview of the top 10 users that tweeted about at least one of the three innovation hubs. Not surprisingly, the official accounts of the hubs were amongst those highly active users, with InnovationVilla and iSpaceGh at Rank 2 and 3 with 2193 and 2067 tweets and BongoHive at Rank 8 with 935 tweets.

Table 1. Most active users.

Rank	Top Users	Tweet Count	Twitter Descriptions (Data Retrieved 23 May 2019)
1	UnlockingWAT	2302	@Google Global Diversity Award Winning Program Supported by @ComicRelief Partnered with @iSpacegh to empower #women to #innovate through #technology
2	InnovationVilla	2193	For #entrepreneurs and those who believe in them! #TIV
3	iSpaceGh	2067	An #Innovation #Hub for the Tech & #Entrepreneurial Community in #Ghana. Entrepreneurs and Startups get to Meet, Network, Work and Share ideas here.
4	jkeyison	1660	Co-Founder @iSpaceGH|#TechInnovator|#Marketing & #BizDev Specialist|Advocate for #WomenInTech josiah@jkeyison.co
5	eGotickets	1472	Africa's fastest growing event ticketing house. 😎 eXperience it here! Dial *713*33# or visit https://t.co/64kYgrBDAt 😊 Call +233 24 282 5622 #Events #People
6	myraclera	1271	Fun loving, kids loving, music loving, dance loving, sadist hating, God fearing, phenomenal African Genius. Volunteering enthusiast! #Tadi is bae!
7	ajo_social	1036	Our aim is to connect social Problems to Social entrepreneurs and social entrepreneurs to social problems. We also connect volunteers to opportunities
8	BongoHive	935	Lusaka's Technology & Innovation Hub.
9	iamrobotboy	845	Building your online presence, 280 xters at a time|#Netizen|I wear #Selections from @1stselections|Hubspot Inbound Marketing cert.|Tweets are my own 🧐
10	RunisMedia1	761	Building #DigitalMarketing experiences with ❤️ for great #brands|Email: runismedia@gmail.com

The most active account was 'UnlockingWAT', an initiative "to equip women with Coding, Business Management, Professional Networking and Pitching Skills and access to Funding to kick start their businesses" (Website https://www.unlockingwat.com/). 'UnlockingWAT' offered three courses on business, tech development and graphic design in addition to a mentorship program for women and girls. It is supported by the British charity organization comic relief and partnered with the innovation hub iSpaceGh. The account 'jkeyison' (Co-founders of the iSpace Hub) was a prime example of another trend we saw in the most active user analysis. Amongst the most active accounts, there was a large number of either founders of the innovation hubs or founders of key initiatives that are rooted or located at the hubs. Another example would be 'lukonga', who is Co-founder of BongoHive or 'mbuyu_', who is a co-founder and community lead at Facebook Developer Circles Lusaka that holds its regular meet-ups in the meeting room of the BongoHive hub. In the most active accounts, we also found the two companies 'eGotickets' and 'RunisMedia', which are both based in Ghana and have ties to the iSpace innovation hub. While 'eGotickets' distributes and sells tickets for events in

Ghana, RunisMedia is a digital marketing agency. The account 'iamrobotboy' was also active in the same domain and intensively posts information on digital marketing. The accounts 'myraclera' and 'ajo_social' belong to the same person and focus on volunteering and social enterprises but have no working online presence, and we could find any actual activity outside of social media.

5.2. Hashtags & Terms

Hashtags are indicated with the #-symbol and index key terms, phrases, or subjects. It enables Twitter users to easily follow a discussion they are interested in by allowing them to use it as a link and thereby search for the same hashtags in other tweets. Hashtags are, therefore, an easy way to analyze the topic of a tweet on the most general level. In our dataset, there were a total of 3905 unique hashtags. We could filter out 5 different patterns that were reoccurring when looking at the most used hashtags: (1) country/continent names, (2) events or conferences, (3) entrepreneurial and tech terms, (4) discussion campaigns, (5) tech initiatives and programs. The country and continent names #Zambia, #Ghana, #Uganda and #Africa were used in 6.31% of all tweets, highlighting how important regional geographies are for the innovation community and how much focus lies on the respective country, the African continent and contextual implementation of technologies. This focus can also be observed with geodata and is further elaborated below. The second pattern circulated around events that were closely connected to the technical innovation communities. Examples are '#afrilabsag', which is used for the annual gathering of AfriLabs (network of African innovation hubs) or #gew2016, the Global Entrepreneurship Week 2016. These patterns also matched our findings for most frequent terms, bigrams and term co-occurrences. Terms such as 'sign up', 'apply for' and 'join us' indicated invitation tweets to events or programs that were often also containing the bigrams 'at' 'BongoHive', 'iSpaceGh' or 'Innovationvilla'. The third pattern highlighted general terms that surround the tech and business community in the hubs. Amongst the most used hashtags, #startup, #tech, #IoT, #python or #coworking clearly showed the adoption of global terms that surround the digital innovation community and also gave us a good understanding of community affiliation (startups, coworking, collaborative communities) and focus areas (Internet of things or Python, which is one of the most popular programming language for data science and especially machine learning). Technologic specific terms, such as Python, could also be connected to specific events as seen in Figure 2. For example, the use of the term, Python, only became relevant with the introduction of the Datahack for Financial Inclusion initiatives that launched at the end of 2017.

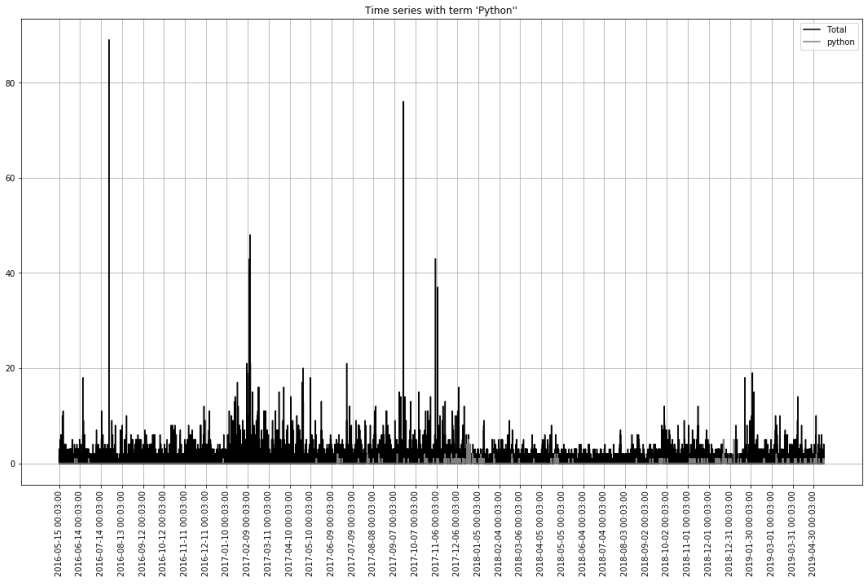

Figure 2. Time series with the term Python.

By looking at most frequent terms, we can also see that many tweets contained the bigrams 'how to' and 'learn more', which indicates the distribution of tutorials or other material that is considered as a resource for learning in this entrepreneurial tech space. The fourth pattern we recognized is about campaigns that focus on creating and bundling discussions about specific topics. Examples range from #talkbiz, a hashtag from Ghanaian entrepreneurs about everyday business questions and talking points to #herfutureAfrica, a hashtag that specifically targets women in technology and encourages learning and female business activity. The last pattern highlighted that many tweets are targeted at different tech initiatives and programs. Some of those programs are locally bound, such as unlockingWAT courses at iSpace in Ghana, while others are African wide initiatives targeting specific entrepreneurial and social problems. The most frequent example in our dataset was #datahack4fi (Datahack for Financial Inclusion), an initiative that provides courses and mentorships in data science to foster financial inclusion on the African continent.

5.3. Geographic Information

In our dataset, we retrieved geo data from two sources. First, from GPS information (if enabled by the account) and second from voluntary location details that were put in the profile information. We created a heat map of all accounts that tweeted about the three innovation hubs and were located on the African continent (see Figure 3). The first obvious observation was that the three cities the hubs are located in—namely Accra, Kampala and Lusaka—also mirrored the most activity in Africa. Above that, we can see interesting patterns that first showed clear regional affiliations and second highlighted hotspots of technological innovations in Africa. For Western Africa, the number of accounts tweeting about innovation hubs pointed towards three cities. While the first two—Accra and Kumasi—are the technological innovation centers of Ghana, Lagos hosts several innovation spaces and is a central force behind the growing digital economy on the continent [19]. In Eastern Africa, we saw Kampala as the most active location due to it being home to the Innovation Village hub. But similar to the western part of the continent, it is surrounded by technological hotspots, such as Kigali, Dar es Salaam and Nairobi. The later one sometimes being referred to as 'Silicon Savannah' [68] that has been a focus place for many stakeholders who are working in the technological innovation environment in Africa. For Southern Africa, the pattern of regional affiliation continued with the representation of Lusaka as home to the BongoHive hub and Ndola as the capital of the Copperbelt that is famous for its technical universities and engineering. Simultaneously, Johannesburg and Cape Town also stood out as two cities that host many accounts that actively take part in communicating about innovation hubs.

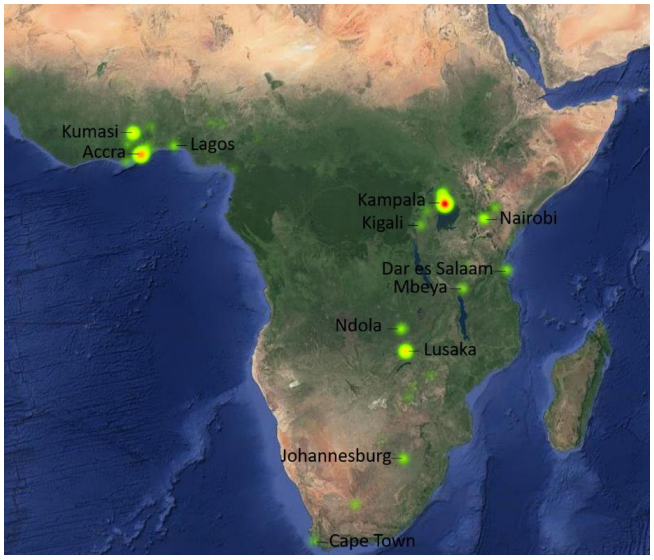

Figure 3. Geographical distribution of Tweets from Africa.

What was evident about geographic location in our data set is the overwhelming domination of urban areas and the clear spotlight on certain hotspots that were not hosting one of the examined hubs but nonetheless seemed to be home to important stakeholders who participate and shape the digital innovation landscape around them.

5.4. Network and Relations

In addition to the above elaborated fundamental metrics, we also utilized methods from network science and visualized the connections that were created through mentions, replies and retweets. We created two network graphs, each giving us a different perspective on how accounts interacted with each other and how we could determine influence of stakeholders within online spaces. Figure 4 shows all accounts that have been mentioned at least 80 times within the three-year time span. This setting was not only used to improve the graphs' readability but also to filter out noise from the dataset that tampers with the core network's components. Mentions function as tags and gave us a good overview of different communities in our data by mapping the marked relations. The direction of connections is indicated by the curve of the link (clockwise away from source node). First, we adjusted the size of each node to the in-degree of mentions. Therefore, the larger the size, the more often the account was mentioned. Secondly, we delineated communities with the modularity algorithm [59] and assigned each community an individual color. Unsurprisingly, the investigated hubs form three unique communities with the hub's account at the center of the network. For our discussion on how to analyze influence in these communities, we evaluated the connecting elements between the three hubs as most important. We identified six major accounts that created linkages between the hubs. AfriLabs is functioning as an umbrella organization of African innovation hubs and organizes conferences, workshops and other platforms for communication. IHub, on the other hand, is one of Africa's first and most famous innovation hubs located in Nairobi that enjoys a high reputation and is a central player in the innovation sector of the continent. If we look at the complete data without filter, we can also see that there were many more hubs that acted like bridges between the three analyzed ones. J4Mtambalike is a key figure behind several good government and social driven tech initiatives as well as a partner at SparkSahara, a company that organizes East Africa's largest innovation and technology event (Sahara Spark). ABANAngels (African Business Angel Network) and VC4Africa are two organizations that work in the startup investment sector. From these connecting elements, we can derive at least two interesting insights: First, innovation hubs in Africa are very well connected to each other through both individual (hub-to-hub) and institutional (umbrella groups) connections. Second, there is an active startup investment community that engages with innovation hubs online and organizes various conferences and meetings to connect investors and digital entrepreneurs.

After looking at communities and key bridge actors between them, we analyzed replies that indicated the direct exchange of ideas and the discussion of topics that were relevant to all involved parties. Figure 5 shows all replies with a filter of 70 to capture the most active interactions. The size of the nodes represents the out-degree of replies, highlighting how many times an account replied to someone else's tweet. The curve of the connection again shows the direction (clockwise away from source node). We can see that the accounts of the three hubs were very active in replying to their own tweets indicating that they answer questions or clarify their initial distributed information. Because the number of interactions often did not say much about the scope and range of influence, we next calculated the betweenness centrality for each node. This method explains the position of accounts that determines control over information flow and highlights the stakeholders who have the most power over steering and directing information flows. Here we can see that it was indeed not the hubs' accounts but instead the three founders ('lukonga', CKJapheth', 'jkeyison') who held three out of the top four most influential positions in the network. We can also see that these three accounts were amongst the most active discussion participants (both input and target of questions or remarks) within their own respected hub community, indicating their status as representatives of their own local innovation community. Above that, we can identify one overarching connecting element

that functioned as the key bridge between the three hubs and was already visible in the mention network above. 'J4Mtambalike' held the most influential position when it came to replies in the twitter online space by participating in intensive and regular exchanges with all three investigated hubs, and here especially with their founders. The account being closely linked to SparkSahara and actively communicating with umbrella initiatives, such as AfriLabs or ABANAngels, again highlighted core actors in the innovation niche and how they were connected through central initiatives or key people in addition to their ability to transfer information into their own communities.

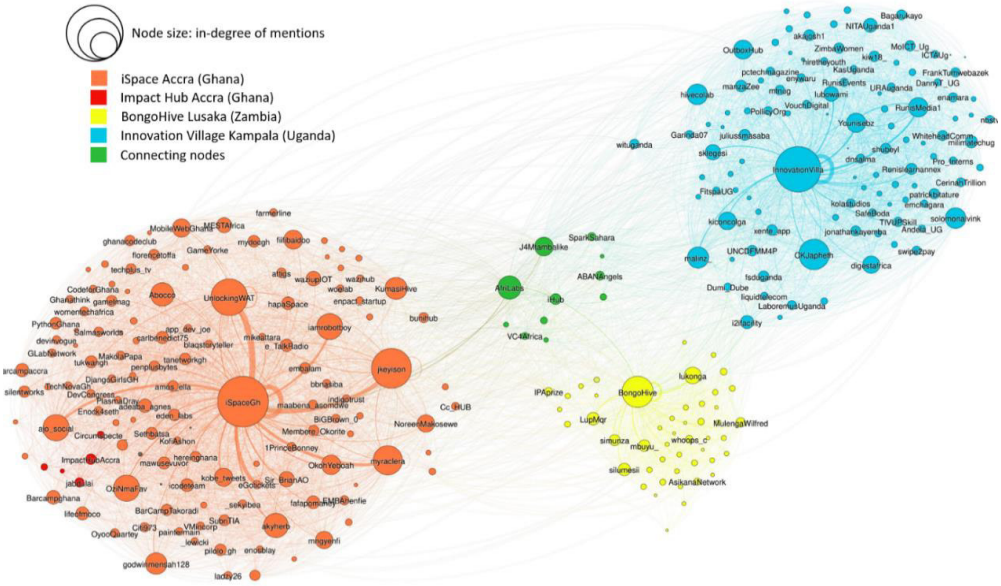

Figure 4. Mention network of Tweets.

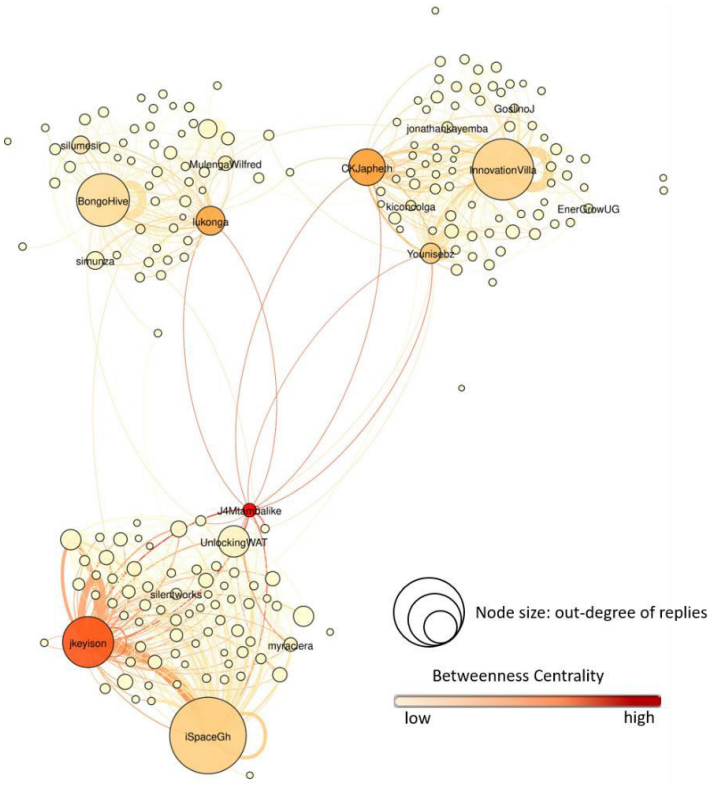

Figure 5. Replies network of Tweets.

6. Discussion

Digital innovations play a key role in fostering sustainable transitions in the Global South. With a growing number of innovation spaces, the next wave of information and communication technology-based applications tackling sustainability challenges is prepared to come from local stakeholders, who are qualified to combine contextual implementation knowledge and technological capabilities. Accordingly, understanding how these production environments for digital innovations function gives new complementary insights into sustainability transitions. By combining our above elaborated theoretical frameworks for space and scale in networks and the concept of innovation intermediation, we want to discuss a number of insights that we draw from our analysis on online innovation spaces.

Innovation hubs in Africa lack relevant links between actors who form the core local network of the respected hub. Instead, the observable connections between the hub's communities are dominated by umbrella organizations or initiatives, hubs directly communicating with each other and hub's founders communicating with each other. Because we can clearly show that the hub's and founder's accounts also hold very dominant and influential positions within their own hub's integrated community, we can derive that they occupy intermediary roles. Especially the founders of innovation hubs share many links amongst each other and function as the whole networks' interconnecting nodes. These positions bridge their own community with other similarly structured communities across the continent and therefore, possess the ability to filter and steer discussion and talking points around digital technology and entrepreneurship. Our data also indicates that the connections between innovation hubs are fostered through umbrella groups, such as AfriLabs, or events, such as Sahara Spark, that again do not target the broad masses of local innovators but instead create links between key stakeholder, such as founders, and important group leaders. By shaping the innovation community's discussion and talking points, these highly influential positions, therefore, play a key role in niches in which new digital sustainability innovations are developed, tested and implemented. The same way Gliedt et al. [69] elaborated on innovation intermediaries as stakeholders who link various actions on different scales to influence sustainability development in uncertain and unstable environments, we found key players around innovation hubs possessed similar potential to influence large networks in digital technology niches due to their different communication and action radius. These findings also add new insights into previous research that conceptualizes innovation hubs through the framework of innovation intermediation. Friederici [16] highlighted that hubs in Africa assemble previous distant innovation actors and redefine new opportunities for them. We can now see that the assembly process does not only connect local actors to a locally bound innovation network but additionally links them to global network structures that are introduced and translated by key community facilitates, which actively shape ample and far-reaching global structures.

From a geographical perspective, our data analysis demonstrated a vast concentration of activity in urban areas, which is no surprise considering the advanced infrastructure for information and communication technologies in cities [70,71] as well as the hub's locations in urban areas. At the same time, many sustainability challenges in Africa are drawing on structures in rural areas and highlight digital solutions for agriculture or energy systems [72,73]. We, therefore, evaluate the trend of digital technology being shaped, developed and concentrated in urban areas as an interesting field for future research to determine how this sharp contrast of production and implementation environment affects sustainability outcomes.

For the field of transition research in the Global South, we wanted to highlight the importance of understanding where local born digital technology was created and in which niche environment it was tested. We found that all larger initiatives which were linked to or originated in at least one of the inspected hubs had strong affiliations with the sustainable development ideology and therefore, pushed the development of digital solutions in this context. Examples range from digital inclusion (Datahack for Financial Inclusion) to gender equality (UnlockingWAT). By bundling talking points under hashtags, such as #herfutureAfrica, we can see how the hubs are active drivers behind creating

inclusive environments for new innovations. In short, the connection to the sustainable development goals (SGDs) is heavily advertised and builds large foundations of those key initiatives. At the same time, the online space around hubs clearly showed their affiliation with their countries, highlighting the contextual innovation approach and their niche testing and implementation environments. These innovation niches across the continent of Africa have a lot in common, such as a focus on data science, financial and gender inclusion, start-up spirit and flexible co-working arrangements. Due to technology's missing ability to function in any given societal setting [74], it is of key importance to understand the production environment behind technological innovation. We, therefore, advocate for further research of inherent characteristics that are introduced due to the innovator's embeddedness in network structures, such as global hub communities and organizations and ideas that influence these very networks. We also want to promote the idea of understanding innovation hubs as niche environments that form local networks of like-minded innovators and entrepreneurs that are connected to a wide-ranging network of similar niches.

7. Conclusions

The purpose of this article was to combine transition research in Africa with a better understanding of digital innovation environments (innovation hubs). We conceptualized these innovation hubs as niches and innovation intermediaries that not only create communities to develop, test and implement new technology but also function as networks to discuss and form new ideas around innovations [16]. With methods from network science, we analyzed influence within and between these communities and showed how a relational network perspective provides new insights into the debate around production settings of digital technology.

Our key findings include the accentuation of key stakeholders, who occupy central positions in innovation networks. These positions enable them to connect similar global communities to each other. Through overarching and not locally embedded initiatives, these key stakeholders participate in wider discourses around innovative technology. The gained influence in return, allows them to steer and regulate discussions in their own local innovation environment. Furthermore, we saw a divide between urban and rural areas as well as a focus on the sustainable development ideology. With these key findings, we want to highlight two major insights for understanding niches for digital innovation. First, Science and Technology scholars have long highlighted the interdependency of technology and societal structures in the form of socio-technical system approaches [75] and the multi-level-perspective [4]. Case studies have shown that technologies are not created as neutral tools but instead contain specific social structures (e.g., network power within Wikipedia's editing structures [76]). We, therefore, advocate to analyze and understand the production environment of these technologies not only as a niche where these technologies are adopted and tested but also as a space where ideas and discourses shape, delineate and condition new innovations. Second, although we found clearly structured local communities around innovation hubs, their out and inbounded influence is managed through key stakeholders who possess the ability to weight and control innovation processes within their own niche. Due to the statistically significant impact of human capital on the adoption rate of technology [77], we want to emphasize the importance of understanding human network connections and the way new innovative ideas and discourses enter local innovation communities. This is especially important due to many information and communication scholars in the Global South highlighting the powerful societal transformation capability of technological innovations and its often-accompanied unintended side effects [78]. Because more and more transition scholars are concerned with the implementation of new technical systems in the Global South, we want to draw extra attention to the production environment of those technologies. As highlighted in this article, the production environment is of equal importance and at the same time, has not received the same attention in scholarly literature. We, therefore, call for more research on the innovators and their networks to better grasp the impact their technologies have once they are implemented and used.

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4.3 Article III — Combining ICT4D and the MLP

Title: Perspectives on Linking Digital Transformation to Sustainability Transformation in the Global South

4.3.1 Background

This dissertation started with an experimental idea: combining theory from the STS oriented Sustainability Transformation Studies with the more classical developmental geography perspectives on societal transformation and ICT4D. As the theory evolved, so did the methodology, combining classical, more qualitatively oriented social research with experimental digital and qualitative Network Science methods. The final part of this dissertation therefore aims to build another small part of a bridge between the disciplines. One could say it tries to show that the two sides are closer related in the sense of an combined interdisciplinary environment than it seemed at the beginning of the research. For this last bridge, three from my point of view core insights from the field of ICT4D Research are presented to then integrate them into the transformation concept of the MLP. Therefore, this article starts not only at the commonalities and integrations, but deliberately also where it becomes clear how the complex areas of digital transformation in the Global South, with all its inherent problems, come up against the purposeful conversion of entire social and economic systems in terms of sustainability transformation.

Why is this conceptual convergence between classical development research (represented by ICT4D) and the application of MLP in the development context necessary? Development research looks back on a long history of different approaches: from once rather large-scale concepts that try to steer whole countries, regions, or sectors as an entity in a certain direction (e.g. modernization theory or dependency theory), to medium-scale theories that rather refer to the contextuality of development work on a small scale, to post-development approaches that critically accompany the Western concept of development as a whole (Korf & Rothfuß 2016). All of these influences have also shaped research on information and communication technologies in the Global South. In this

relationship, MLP, a framework for understanding large-scale transformation processes that originated in the global North, is a very recent analytical framework that, by design, always seeks to include the bigger picture, i.e., larger-scale contexts. Although it is true that processes and dynamics within the niche or the regime are often differentiated into small parts as an object of investigation and thus attain enormous depth of detail (cf. article I on cultural legitimacy in the niche). However, the complexity of the overall picture is always emphasized as an overarching framework by incorporating and ultimately centering the interdependencies between niche, regime, and landscape. This discrepancy between the two scientific 'disciplines' can be illustrated very well by two quotes. First, from the perspective of ICT4D research represented by Walsham (2017), and second, from the perspective of MLP represented by Wieczorek (2018):

> "But we should not see ourselves as the "experts" bringing top-down solutions to 'beneficiaries.' Rather, we should see ourselves as co-contributors with everyone else, since all people throughout the world have views about "development" in their particular context." (Walsham 2017: 37)

> "What transition studies add to these debates is the way of framing of the complex processes, and therefore also ways of seeing the bigger, systemic picture, making the context and its impact more explicit and articulated, factors which development studies have not considered in great length" (Wieczorek 2018: 210).

Thus, although the objects of research are similar, the applied theories for analysing and understanding development or transformation processes have partly different approaches. While the MLP keeps the big picture in mind, it therefore runs the risk of undervaluing the comprehensive findings on the dangers of complexity reduction and not paying adequate attention to context and that were established by the ICT4D research community. This is particularly relevant in a research environment such as the Global South, where heterogenous realities of life coexist and sometimes clash in extreme forms.

This 'weakness' of the MLP in the Global South is particularly evident in the analysis of digital technologies. Because, as pointed out in the previous two articles, digital technologies can set in motion highly scalable and disruptive changes. Moreover, the niche often gets legitimacy from outside rather than inside application spaces (Schmitt 2019), and the inequality of society in any case raises strong power questions about the direction of transformation or development paths in the Global South. Therefore, in my opinion, a structured embedment of the MLP into the insights of development research is

needed for its further use in the Global South. A first step for this coordination shall be done via the analysis in the following article "Perspectives on Linking Digital Transformation to Sustainability Transformation in the Global South ".

4.3.2 Integration

Since this article is not based on own empiricism like the other two, but rather on an analysis of existing literature, the integration into the overall context of the work is also different from the previous two articles. Here, attention will rather be paid to overarching questions of the integration of MLP into the development context, which is primarily, of course, about the comparison with already existing approaches to development or transformation research. Therefore, this integration will not refer directly to the central research question, but rather discuss the extent to which the two disciplines of transformation and ICT4D research share similarities. Finally, the three lessons from ICT4D research listed in the article will be used as an example to show how the 'bigger picture' of MLP can be meaningfully brought together in combination with insights from development research. Relatively, why it can be a profitable added value for the two approaches of the respective discipline discussed in the following to engage with the insights of the other discipline and to incorporate them into one's own theoretical work. In this sense, this integration of the article into the Envelope reflects not in particular the actual research question, but in retro perspective also my own lessons learned from the 'mixing' of classical development research and socio-technical systems research. Or, in other words, just as interdisciplinarity has already been discussed methodologically (see Chapter 3), the symbiosis at the level of theory, i.e. of MLP and the ICT4D field, will be addressed here.

Anyone who studies development and transformation research quickly recognizes a fundamental dilemma. Both scientific disciplines address the change from one status to another status. Both disciplines have two parallel perspectives that examine this change. On the one hand, an 'active' perspective, in which the target image is predefined and the question of the best possible way to achieve the target is in the foreground (Feola 2015, Korf & Rothfuß 2016). On the other hand, an accompanying perspective that places more

emphasis on the objectivity of the analysis of the change and does not claim to be normatively guided. So, while what initially looks like a big difference, it can nevertheless be broken down to a lowest common denominator. Namely, understanding the underlying system, including its developmental and transformational processes taking place, without which neither analysis nor control is possible. While the 'active' perspective uses the insights from the understanding of the system to address applied questions about the governance of change processes, the observational perspective is concerned with the understanding of the system and process itself. Most studies working with MLP in the Global South are clearly on the active side (compare Hansen et al 2018, Nygaard & Bolwig 2018 or Sixt et al 2018). In contrast, this thesis' own empirical research is always based on the observational and analytical perspective, which has no claim to active intervention. Thus, when applying MLP to the development context or in the Global South, it should first be noted that both sides can use the theoretical framework around the niche, regime, and landscape for scientific analysis.

So while both the discipline of ICT4D and the MLP share the same goal of understanding transformations and development processes, the differences arise in the question of scale. The MLP as a framework aims at adding a "bigger, systematic picture" to transformation processes, while ICT4D developed into a narrower, contextuality focused discipline. This is because while the MLP places a large focus on the interconnectivity between factors of different parts of the overall transformation picture (i.e., the interactions between niche, regime, and landscape, c.f. Geels 2002), the ICT4D field lacks such a dominant and overarching theory as a basis for the impact of technology in the Global South. Vice versa, we see detailed and highly contextualized research in the ICT4D field that, while less aspiring to produce a transferable overall theory, is instead more open to interdisciplinary influences, such as equity or (capability) access debates. Although these significant differences might give the impression that the two approaches cannot be directly linked, we argue the opposite in the article. And this lies much less in the differences than in the three commonalities and points of connection between the two perspectives discussed below.

In the article "Perspectives on Linking Digital Transformation to Sustainability Transformation in the Global South," we first use the example of digitalization to show how sustainable shifts of social, ecological and economic structures merge with disruptive digital technologies in the Global South. If we look at the drivers of accelerated transitions in this context, we see that historically systematic changes take place through influences at a variety of levels (Sovacool et al. 2020). For example, if we look at the local, i.e. limited to a specific context, we see the defection of incumbent actors to innovative experimentation spaces (Bumpus & Comello 2017), or innovation hubs focused on specific markets and social factors (Friederici 2016). They explain why certain digital innovations prevail in certain contexts studied. In other words, the question is how structures form in the niche to challenge and ultimately replace the status quo in the regime. In terms of transformation studies, then, the focus is on the enforcement of the new structures. In terms of transformations that proceed on the basis of technological innovations, a new dominant mode of social structure is brought to the fore that attacks existing regime structures through the possibility of technological scaling. Or simply put, technological innovations empower a greater scope of action for actors in the transformation process. Thus, to understand not only how new transformations grow out of the niche, but also to consider the side effects of technology-fuelled centralization of power, requires more than a rigid view through the MLP. In the article, we therefore use this observable process to show how development studies and MLP can complement each other, using the first of three examples. For this purpose, we draw on Amartya Sen's capability approach (Sen 2001), which emphasizes the relevance of freedom of choice and thus the aspect of power within transformation processes. The core aspect of this combination of Sen and the MLP is the integration of different ideas of development into transformation processes. Thus, from a research perspective, it ultimately opens up the opportunity to understand not only new social change, but also the differentiated conceptions that must give way to other conceptions in the niche or regime. In transposing MLP to the Global South, a context already characterized by strong tensions and extreme power differentials (Dados & Connell 2012), we therefore argue for the inclusion of power concepts (such as the capability approach) to account for the particular circumstances of the research setting.

As a second example of how MLP can necessarily be complemented by developmental approaches, we cite in the article the specifics of contextuality in digital production processes. Here, the danger to accurate research using MLP is seen as the fact that technical innovations have a historically strong relationship to global influences that are to be located in the landscape. Particularly with regard to the production environments that are central to the research, predetermined breaking points arise between small-scale, local social structures and higher-level processes from the global world of technology in the landscape. The core problem here is the acceptance of technological innovation by means of as little social disruption as possible, leading to the best adaptations and outcomes in the Global South from an ICT4D perspective (Unwin 2017). In combination, contextuality therefore makes it important to not only consider the landscape as pressure 'from above', but to include the consequences of disruption within transformation processes on deep societal structures 'from below'. Put simply, when analysing the success (neutral: progress) of digitally underpinned transformations, the pressure of the Landscape must not only be understood as a global, overarching construct. Rather, the Landscape must additionally be conceptualized as context-specific and long-established structures of local conditions.

The third and final example of the possible 'merging' of MLP and Development Studies circles around the necessity of a politicized understanding of resources and sustainability. Based on the two scales of transformation research and ICT4D research, the debate around "justice" shows how difficult an adequate understanding of transformation processes can be in the research context. On the one hand, one sees the small-scale approach of development studies, taking into account different understandings of development and various participation levels of all actors involved. It culminates in the understanding of "justice" that at the small scale an enormous difference can take place between social impacts of transformations and the quality of inclusion (Bennett et al. 2019). On the other hand, one sees the focus on the big picture of sustainability transformation in terms of a normatively superior direction that does not allow that direction per se to be challenged by actors. While the theoretical framework of MLP does perceive the activities of actors or institutions that understand justice in terms of participation, direction and inclusion possibilities of a transformation process as resistances, it does not have an adequate

response to systematically capture these complex social contexts. At least not in the context of the Global South, which is characterized by its enormous conflicting diversity between indigeneity, tradition, colonial history, Western influence and hybrid structures.

As a proposed solution for the inclusion of a justice understanding in theories of transformation research, as it has proven itself in development research, we therefore go into more detail in the article on the three levels of justice introduced by Benett et al. (2019): 'Recognitial Justice', 'Distributional Justice', and 'Procedural Justice'.

The quintessence of our analysis is to point out the different nuances that a normative concept of justice entails and how transformation processes can lead to friction points on various levels. We do not however actively try to address these frictions in detail, but rather raise awareness of them to be included in MLP-related research projects that tend to be less sensitive for such small-scale analysis in the Global South (Wieczorek 2018). Thus, we follow Feola's (2015) descriptive-analytical approach, which understands the research object of the transformation process as emergent rather than problem-based.

The article "Perspectives on Linking Digital Transformation to Sustainability Transformation in the Global South" aims to better connect two previously poorly connected disciplines. Based on the three examples shown and the underlying theoretical constructs, we would like to demonstrate that a bridge between the research fields can provide a valuable basis for initially new interdisciplinary research approaches and subsequently also new interdisciplinary methodologies. Thus, in a way, this article is meant to be the final piece of the puzzle that complements the overall picture underlying this dissertation: an interdisciplinary approach to the topic of social transformation in the context of digital technologies in a highly complex context of the Global South. Thus, while the two empirical papers emphasize the usefulness of transferring the MLP to the context of the Global South, this article pays a decided attention to the non-negligible problems that arise in that very transfer. But not without also providing first theoretical thoughts for the resolution of these problems and finally giving further incentives for the successful further merging of the two disciplines.

4.3.3. Article III

Article not published yet.

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Perspectives on Linking Digital Transformation to Sustainability Transformation in the Global South

Introduction

In recent years, digital technologies, especially information and communication technologies and the immense collection of data and their processing by means of sophisticated data analysis, have rapidly expanded in availability and scope. It is therefore not surprising that digitalization is widely considered as one of the key drivers behind economic and social advancements. In accordance with the notion of socio-technical systems, many scholars in recent years have emphasized the disruptive potential of digital technologies in accelerating transformation processes, making them all the more relevant to the discussion of low-carbon or sustainable transformations (Dabrowska et al. 2022).

In the global South, a socioeconomic context defined by its diversity (Francis et al. 2020), these processes are undoubtedly equally important. The duality of traditional and indigenous structures on the one hand, and the ever-increasing integration of changing economic practices and contemporary state and civil society frameworks on the other, vividly illustrate the complex tensions the global South faces. In addition to these tensions, which are generating their own transformational dynamics, another driver of transformation is now emerging with the introduction of new digital technologies. The combination of these disruptive digital technologies with the pressure for change from the sustainability movement in the Global South is thus giving rise to new, unique structures whose developments have not yet been placed on a sufficiently conceptually sound footing. New questions that emerge from this process can be sorted in three categories: First, an understanding of unique structures in the Global South that cannot be adequately mapped and explained by an oversimplified adoption of ‘outside’ transformation frameworks. Second, a rapid development and implementation of digital applications that disruptively affect entire societies. And third, a conscious transformation process toward sustainability, whereby sustainability here deliberately encompasses not only

environmental dimensions, but also takes social and economic factors into account in a holistic approach.

The conceptual explorations in this article therefore start where digital technologies, sustainability transformation and the existing complex tensions in the Global South meet. The associated structural disruption of social systems (transformations) should therefore be considered in a compellingly transdisciplinary way. In this way, this paper summarizes three basic findings from ICT4D research (Information and Communication Technology for Development), a small but very vibrant research branch that is concerned with the effects of technology in the Global South: (1) a fundamental understanding of stakeholder's freedom to choose their own development pathways in connection to information and communication technology (Sen 2001, Kleine 2011), (2) the tendency of digital transformation to create new power dynamics through various levels of access and benefits (justice debate) (Lampinen et al. 2018), and (3) the effects of rapidly growing local innovation hotspots for digital development (Schmitt 2019, Schmitt & Muyoya 2020).

In a second step, this article aims to combine these ICT4D perspectives on digital technologies with perspectives of sustainability transformation to allow the field an easier entry and a first step towards a fundamental conceptual outlook. This is done by linking the discussed ICT4D discourses with the multi-level perspective (MLP). With the subdivision of landscape, regime and niche, this framework is widely used in the field of socio-technical transformation, as it makes it possible to analyse and explain the various influences and interactions between actors and institutional structures on macro, meso and micro levels. The landscape represents deep structural arrangements and trends that tend to be highly resistant to change, but at the same time have pervasive influence on regimes and niche levels (e.g. climate change or capitalism) (Geels 2002). Regimes, on the other hand, are characterized by the organization and structures of a social arrangements consisting of prevailing and enforceable rules, institutions, and technologies. With regards to socio-technological systems, the regime consists of a combination of social and technical components that constantly reinforce conformist dynamics and tend to impede new developments through stable structures (Fuenfschilling & Truffer 2014). To break up these lock-in effects with the help of landscape developments, niches are formed that generate new innovations and offer protective functions against fixed regime structures. Optimally, niches create safe spaces in which new socio-technological ideas can emerge and mature in order to ultimately compete with regime structures.

Combining this proven transformation framework with digital disruption in an already complex transformation process in the Global South is a necessary next step when it comes to research in this interdisciplinary context. We want to initiate this step through the following article structure: first, we

illustrate the relevance of digitalization for sustainability by highlighting the interconnectivity of digital and sustainability transformation using the example of low-carbon accelerations. Then, we will discuss some peculiarities of digital technology in the context of the global South before introducing the basics of the three above mentioned research findings from an ICT4D perspective. In the last section, we will present a conceptual outlook and show how transition research based on the MLP in connection to the elaborated ICT4D fundamentals can be valuable in the global South when investigating socio-technical systems that include some type of digital components.

1. Digital and Sustainability Transformation in the Global South: connecting the dots

"In almost all areas of business and public sphere the digital transformation is often disturbing or even shaking up the current order of market places and organisations. Development in the digital area during most recent decades has made the possibility and fear of being disrupted by new business models using digital platforms, communities, digital services and a suite of new technologies more present." (Rosenstand et al. 2018: 1)

"Effective mitigation of climate change will require transitions towards low-carbon electricity, heat, agro-food, mobility and other systems. Since existing systems are locked-in and path dependent, these transitions will involve disruptions of the status quo and transformational changes in technology, user practices, markets, business models, policy, infrastructure and cultural meanings." (Geels 2018: 224)

As highlighted by the above quotes, both the sustainability transformation and the digital transformation are considered two of the greatest drivers of our times (Geels 2018, Grey & Rumpe 2015, Nidumolu et al. 2009, Rosenstand et al. 2018). It is therefore hardly surprising that the symbiosis of the two is an increasingly observable process for a variety of scientific disciplines. While both the fight against climate change and the rapidly advancing digitalization are changing social structures in their own right, a closer look reveals how intertwined the two transformation processes have become. Exemplifying this development is the mutual importance of digital technologies and the acceleration of low-carbon transitions to achieve long-term climate goals. According to figures from the International Energy Agency, only four of 38 sustainable energy technologies are currently on track to meet long-term climate goals: LEDs, electric cars, solar PV, and data centres, which all have a direct or indirect relationship to digitalization (IEA 2019, Sovacool et al. 2020). The symbiosis of digital innovations and the acceleration of low carbon transformations is self-evidently particularly clear in the modern design of data centres. Two of the best-known examples of this are the effective capacity utilization of servers according to their workload, pioneered by Google's DeepMind (Gao 2014), and the optimization of cooling processes through digital model-prediction control (Lazic et al. 2018). In particular, this shows that large-scale digital data collection is an important component of future

energy efficiency, which vividly highlights the link between sustainability and digital. But this trend can also be observed in the field of solar PV and electric cars. Not only are electric cars increasingly being used as a core segment within new mobility concepts, but also the relevance of smart grids in terms of decentralizing energy production through solar PV and increasing efficiency in energy consumption indicate that a low-carbon transformation is no longer conceivable without digital components (Gercek & Reinders 2019). Some of these developments already have a strong relevance in the Global South, while others, although most likely to be adapted in the long term, are currently rather unimportant. For example, a large part of the growing energy demand in Africa is generated via solar energy (Adenle 2020). In the medium term, a new power grid on the continent will therefore not be able to avoid sophisticated smart grid technology. The same applies to new data centres, which have been gaining in importance for several years, especially in the regional strongholds around Kenya, Nigeria and South Africa.

Beyond these empirical examples, this trend can also be clearly mapped at the conceptual level. Sovacool et al. (2020), for example, summarize which drivers are essential for accelerating low-carbon transitions at the three levels of the Multi-Level-Perspective (MLP) (landscape, regime and niche). The following table 1 links these results with associated digital trends and examples from the global South, again illustrating the interdependencies and concordances with regard to accelerations.

	Drivers of accelerated transitions (based on Sovacool et al. 2020)	**Examples of associated digital trends**	**Research and practical examples from the global South**
Landscape level	External shocks	Disruption of processes through digitization (efficiency gains)	Push for industrial energy efficiency in Ghana (Apeaning & Thollander 2013)
	Gradual Trends	Datafication (Mejias & Couldry 2019)	Datafication in the context of marginalized urban communities (Heeks & Shekhar 2019)
		Better access to information and communication technology	Worldbank's Digital Infrastructure Moonshot project for Africa: reaching universal access by 2030

			(Broadband Commission 2019)
		Steadily improving digital literacy	Inclusive digital literacy framework in India (Nedungadi et al. 2018)
		Advances in e.g. AI technology	Predicting mine water quality in South Africa (Sakala et al. 2019)
Regime level	defection of incumbent actors towards niche-innovation	Collaboration between incumbent firms and digital start-ups (Islam et al. 2017)	South African cooperation between Santam and CTRL (Insurance-tech)
		Incumbent actors acting as capital provider for Niche innovations (Bumpus & Comello 2017)	Vodafone financing the development of mobile money innovation M-PESA (Jack & Suri 2011)
Niche level	Expansion of coalitions	Accelerator programs for digital start-up innovations	Rise of innovation hubs (Friederici 2016)
		Founding of innovation and collaboration platforms of incumbent firms	IGNITE Agri-tech accelerater (Connolly et al. 2018)
		Governmental and NGO coalitions to foster digital trends	ePhyto Blockchain solution by the UNICC & IPCC
	Positive discourses and visions that appeal to mass public	wide-ranging futuristic discourses on the capabilities of technologies	Adoption of outside futuristic discourses about Technology in Zambia (Schmitt 2019)
		Digitalization as core identity of solutions to problems: technological determinism (Wyatt 2008)	Legitimacy creation of digital technology (Schmitt 2019)
	Rapid technological improvements and cost reductions	Advancement of chip technology, exemplary for increasing computing power	Moore' Law (Schaller 1997)
		Progress in autonomous systems (AI)	Google's AI Research Center in Ghana
		Quantum computing	/

		Cost reduction of devices	Lower device and transaction costs for agriculture in Cameroon (Minkoua Nzie et al. 2018)
	Major policy changes that alter selection environment	Cross-industry introduction of digital policy (e.g. EU GDPR)	ICT policy thresholds for supporting female employment (Asongu & Odhiambo 2020)

Table 1: Transition acceleration, digital trends and the global South

Using the example of the low carbon transformation as a sub-area of an overarching sustainability transformation, it can be clearly illustrated how digitization and sustainable shifts of social, ecological and economic structures merge in the Global South. In this context, from a scientific perspective, the question arises to what extent transformations can be better understood in the context of technology, sustainability and the Global South. Or to put it differently: How can proven concepts such as socio-technological systems and the MLP offer added value in the analysis of transformations in the Global South? These questions clearly indicate the interdisciplinary nature of the problem, which is why this article combines the perspectives of development studies and transformation scholars.

2. Development discourses and sustainability transformation

Although the systematic application of socio-technical system and transition approaches in the global South is still in its infancy, there is already some research that is gaining insights in this area. As Wieczorek (2018: 204) states, "various models developed in this field aim to explain how transitions unfold and how to govern them. The most fundamental model, which has also formed the basis for other approaches, is the Multilevel Perspective on system innovation (MLP)."

"What transition studies add to these debates is the way of framing of the complex processes, and therefore also ways of seeing the bigger, systemic picture, making the context and its impact more explicit and articulated, factors which development studies have not considered in great length" (Wieczorek 2018: 210).

The global South is characterized by the complex coexistence of different structures. Extreme poverty can coexist with extreme wealth, traditional social systems with new ideas of society. This is the reason why today we speak less of poor or underdeveloped countries and more of inequality within a defined context. Contrary to the above quoted argument from Wieczorek (2018), larger systematic pictures do not appear frequently in development studies because they have rarely been considered, but rather because they are declared unhelpful for gaining knowledge at a scale such as the

transformation of fundamental structures (Desai & Potter 2013). Therefore, a blind adoption of MLP cannot serve as the basic conceptual framework of sustainability transformation in the global South. Rather, it must be applied more specifically to the socio-technological context in this diversity-driven environment. In this article, we would like to exemplify this for the field of digital technologies. By showing the relevance of the MLP in connection with fundamental results of years of technology research in the global South, a connecting bridge is thus built between the two fields of development and sustainability research that, as shown above, is needed to understand the complex interlinkages between digital and sustainability processes.

3. Digital technology in the global South

In order to build this bridge, three different areas of development research with digital relevance will be discussed below. First, we will use the example of the Choice Framework to show how desired objectives of development can be understood from a bottom-up perspective. Then, we will look at the relevance of contextuality before classifying the justice discourse in relation to digital technologies in the Global South in the third part.

4.1 Choice framework and digital technology

The study of the active and passive configuration of social systems has a long tradition in science. The actions of persons are always conditioned by structures created by a community of social actors (laws, rules, or also social norms or market logics). Social actors therefore act due to competition, factual logics, power relations or historical aspects in a specific contextual environment. Accordingly, people's lives are connected by practices that are defining societal structures better than categories such as age, gender, or educational attainment (Everts et al. 2011). Derived from this, influences from outside these structures tend to change more than originally intended due to the lack of contextual knowledge about action practices and thus unitedly destabilize whole social systems in the long run. This also raises the question of who decides on the future direction of socio-political structures and the extent to which power relations condition the suppression of room for manoeuvre. In response, Amartya Sen developed the capability approach (CA), which is based on the actor-cantered freedom of choice (Corbridge 2002, Sen 2001). In his work he distinguishes between two basic notions of how individuals act in their respective environments by introducing the ideas of 'Functionings' and 'Capabilities'. 'Functionings' are constructed as the activities and beings of individuals that add up to what can be defined as life, while 'Capabilities' are conceptualized as the actual freedom to access and choose between various alternative combinations of these activities or beings (Sen 2001). It is thus argued that it is not the improvement of the state of life in terms of 'functionings' that is a desirable achievement, but the creation of an environment that provides alternative choices between different combinations of "beings and doings" (Sen 2001: 288). Thus, as a basic principle of this CA, it is

important that actors shape their socio-political environment so that other actors, in turn, have the freedom to choose their own actions. In this way, change can be sustainable and effective because the specific contextual frameworks are taken into account and all actors have the opportunity to act according to their defined needs. The freedom to choose a specific change will thus become more important, and especially more empowering, than the actual change itself. Or as Walsham (2017: 23) formulates it: [...] "the CA focuses on the "freedom" which individuals have to lead the kinds of life they value".

This theoretical school of thought has been highly influential in technology research in the Global South, as it advocates not the solution from the "outside" in a context of poverty and inequality, but the sustainable creation of structures that promote contextual change from within a system based on empowerment (Andersson et al. 2012, Prakash 2007, Walsham 2017). The daring question of how such a framework, concerned with the freedom of choice to live the life one values, can be operationalized in the digital technology context of the global South is thereby explored in Kleine's (2011) Choice Framework for ICTs. In her work, Kleine (2011: 124) states that "[the Choice Framework] helps map complex development processes in which individuals use their resource portfolio to negotiate a given social structure in order to make the choices which bring them closer to the lives they value." Combining this with technology research, she then highlights three levels of analysis: (1) Deconstructing embedded ideologies and analysing goals; (2) Systemic Mapping; (3) Planning for Choice. The first point refers to ideas and ideological principals that are sometimes obvious, sometimes hidden and embedded in every technology (e.g. exclusion/inclusion, individualism/collective action). On the second level, she highlights the interactions of digital technologies with social development processes, which can be revealed through systematic mapping. On a structural level, for example, policies that influence access to ICTs can be mapped, while on an individual level, for example, technological literacy significantly regulates user behaviour. The third level finally aims at practice planning and addresses the fact that users' choices can only be promoted in digital processes if they are already integrated from the design process on. A point of view that is also strongly represented by theories around open and inclusive innovation (Heeks et al. 2013, Schillo & Robinson 2017).

The idea of choice in the context of digital technology in the global South summarizes two key elements for research. First, in a diverse context such as the Global South, digital technologies risk accelerating inequalities by further establishing unequal power relations. Second, digital technologies can be used to increase the decision-making freedom of social actors by involving them in the design process rather than imposing solutions from the outside.

3.2. Contextuality and digital technology

There are two main approaches to analysing technology in terms of a holistic socio-technical perspective. First, through implementation and actual use cases; second, through the design and production phases. While the first focuses on the direct interactions of users with technology and vice versa, the second focuses on what social features are part of the technological production process. This perspective is based on the notion that technology is not inherently neutral and that social patterns, institutional arrangements, and various work practices are embedded in the technological structures themselves (Polgar 2011). Or as Monteiro & Hanseth (1996: 326) frame it.: "[…] buried deep in 'technical' details they inscribe anticipations of individual, organisational and inter-organisational behaviour."

As discussed in the section above on the capability approach, in order to not confirm distinct power relations through the acceleration potential of technology, the contextuality of digital innovations plays a major role in the global South. It is therefore not surprising that innovative digital solutions from local contexts are strongly promoted. This can be exemplified by the growth of so-called innovation hubs, which can be described as a mixture of co-working space, entrepreneurship education program and start-up incubator (Friederici 2016, Jiménez & Zheng 2017) (see Figure 1). Ultimately, they combine two factors: First, they bring together digital talent with computer science skills capable of creating their own digital solutions. Secondly, these stakeholders have an accurate knowledge of their own local context and can thus create a counterbalance to "foreign" technology, which are not easily transferable through different social production environments, because social systems could be subconsciously changed in the process (Unwin 2017).

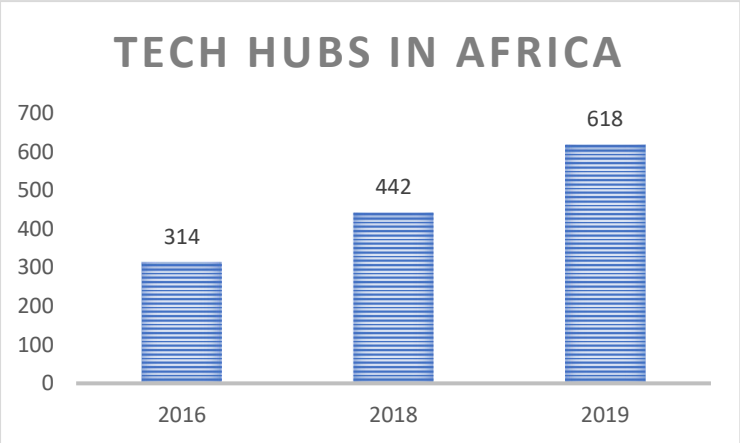

Figure 1: Growth development of tech hubs in Africa (Data source: GSM Association)

There are numerous studies on the impact of innovation hubs on various sustainability and development potentials. Especially with regard to the promotion of entrepreneurial activity, they are seen as a great hope for opening up jobs and new forms of income for entire regions (Adesida et al.

2016, Fagerberg 2009, Hall et al. 2012). At the same time, there is also increasing attention to the potential of knowledge exchange and assembling power, which allows previously unconnected actors to work together on new solutions (Friederici 2016). Yet there is much criticism of this more business-centric approach, which often equates innovation with positive development (Bradley et al. 2012). Here, particular reference is made to the complexity of social systems, whose development should not be measured by a reduction to economic factors alone (Kothari 2019). As a further approach, scholars such as Jiménez & Zheng (2017) therefore argue that innovation can also be seen as gaining agency in shaping one's own local reality. Combined with the argument that technology is most effective when developed by actors rooted locally in the same context as its intended use (Matuschewski 2006, McQuail 2007, Unwin 2017,) the question of how to define and study local context to better understand socio-technical interactions inevitably arises. As initial answers to this question, research by Schmitt (2019) and Schmitt & Muyoya (2020) uses cultural legitimacy and network analyses to show how actors in local innovation hubs transfer international discourses into local contexts. In doing so, they adopt standpoints that have emerged from their exposed position on global processes and thus solidify the complex inequality tensions in the global South. The danger of distancing digital products that have emerged from innovation hubs from their direct socio-structural environment is thus partly just as present as with non-local solutions.

The above research discourses highlight two important aspects. The first thing to consider is the normativity of digital technologies, which can be analysed not only through the implementation processes, but also through the original design process. Second, locally generated digital technologies (such as e.g. from innovation hubs) are considered desirable to better embed local social patterns in technology. At the same time, however, the producers of digital solutions are often strongly embedded in global discourses that can, among other things, alienate them from their local context and therefore negate this effect.

3.3. Digital technology and the challenge of 'Justice'

We agree with Scoones (2016) when he argues that transformation to sustainability requires a shift beyond scarcity discourses towards a politicized understanding of resources and sustainability. This is a critical view which stands against and resists the ongoing reproduction of harmful power relations (Gillard et al. 2016). Following furthermore theses of Schatzki (2002) and his Theory of Practice or, in other words, his 'site ontology' which does not only consider practice but also material and immaterial arrangements as crucial parts of social reality, our attention turns towards the question of social justice. It is one of the challenges of present times to determine, how social inequalities reside in and are produced and perpetuated by various practices. As is argued by Bennett et al. (2019: 1) sustainability transformations cannot be considered a "success unless social justice is a central

concern". A transformation to sustainability, be this in the field of ecological concerns and climate change or in terms of digitalization, calls for radical and systematic societal shifts, which again implies a challenge in terms of environmental justice (EJ) in the broader sense (Temper et al. 2018). Yet, actions taken in terms of shifting social-ecological systems towards more sustainable trajectories can have substantial social impacts. To gain means of environmental adaptation as well as means to participate in the emerging benefits of digitization, people will ultimately be excluded from emerging decision-making processes and advantages of digitization.

Worldwide, people in every social constellation have different access to highly valued and sought-after goods or are excluded from them, especially regarding achievements in the field of digitalization. Variables of different kind define practices of access, be these gender-, income-, knowledge-, or peer-oriented. It is one of the future challenges to find out how such inequalities in access to the digital world reside in and are produced by various practices (Van Deursen et al 2017). One might as well investigate how practices can travel across spaces, get entangled with different practitioners and build up new communities of practice, be these digital hubs or platforms of experience and knowledge exchange in various shapes.

Transformation scholars in general have in various ways engaged with the perspective of social justice. In general, the overarching framework of 'Social Justice' gears our attention towards the structural and relational drivers of inequalities, marginalization and various life conditions framing vulnerabilities, which again define adaptive capacities and processes of exclusion for specific individuals and groups of people (Shackleton et al. 2015). But, as stated by Bennett et al. (2019: 3), "within the research on transformations to sustainability little emphasis has been placed on the differentiated social impacts of such profound change or the level of inclusion of implicated actors in decision making". The same is true, as one can imagine, for a transformation in terms of digitalization, one of the most exclusive undertakings of societies in the Global South.

Against this background the question arises on how to get hold on those social impacts alongside processes of transformation. Bennett et al. (2019) offer some answer: In the course of their argument, they introduce a three-fold scheme defining justice in niche-level contexts further to be expanded to the regime and landscape level. They differentiate between three perspectives of justice: 'Recognitial Justice', 'Distributional Justice', and 'Procedural Justice'. With relation to Recognitional Justice, which is considered as 'basis' of all forms of justice, special attention is to be paid to the representation of diverse interests and the involvement of those groups and stakeholders, who are in general and deliberately neglected and marginalized. This in general means respect for pre-existing governance arrangements and as well the various worldviews, knowledge patterns, needs, livelihoods and cultures

of different groups must be moved to the centre of decision taking in terms of transformation. ‘Distributional Justice’ again is defined as fairness relating to the distribution of benefits and harms of decisions and actions to different groups in space and time. And finally, ‘Procedural Justice’ relates to exchanges when participation and integration into decision making, and the quality of governance processes are explicitly taken into consideration aiming at societal transformation. This justice debate, though so far rather indirect, is in the same vein as a large body of ICT4D research that addresses the representation of interests, the distribution of benefits, and the possibility of participation of newly deployed technologies in the Global South. Singh & Flyverbom (2016: 692), for instance, show in terms of 'Recognitial Justice' how narratives in the deployment of information and communication technologies "account for contestation over meanings of participation." Similarly, in terms of ‘Distributional Justice’, case studies of ICT projects in the Global South show that the scalable benefits often associated with technological progress are not necessarily equally distributed. An example of this is the problem of local language in the context of digital devices in Ethiopia presented by Zaugg (2020). In this case, digital devices were only available in Latin script instead of the local Amharic script. As a result, many end users were unable to operate the devices and, consequently, to utilize the expected benefits. Existing structural inequalities like in this example lead to unequal adaptation and thus to a new type of digital exclusion that mirrors existing (in this case language) patterns. It is therefore evident that access to ICT is not self-evident and that different technical understandings and social structures, such as language, as well as the physical availability of technology, play a significant role in receiving its benefits (Unwin 2017). The last category from Benett et al's (2019) justice discourse also relates well to the adoption and diffusion of digital technologies in the Global South. ‘Procedural Justice’, referred to as "the level of participation and inclusiveness of decision making and the quality of governance processes" (Benett et al 2019: 3881) is the abstraction from what is often characterized in a negative way in the ICT4D context as the lack of involvement of local people, or top-down approach. Described as the "Root Cause of ICT4D Project Failure" (Walton & Heeks 2011: 4), top-down development of digital technologies is always associated with a gap that does not sufficiently consider local realities. The opposite - involving local people in the design and implementation phases - results in contextual relevance and, accordingly, better adaptation to local conditions (Carroll & Rossum 2007). In summary, this means an early and comprehensive involvement of beneficiaries in order to make the governance process of high quality and thus to achieve an explicit (procedural) justice reference in the development and application process of digital technology.

4. Conceptual outlook for connecting the MLP with the above discussed fundamentals of ICTs in the global South

The MLP provides a systematic framework for complex socio-technological transformation processes, offering the perspective of a bigger picture. However, in the analysis of transformation processes that take place in a diverse environment such as the global South, there is a danger of reducing complexity and hiding heterogeneous realities of life. Nevertheless, several research papers have already shown that the concepts of landscape, regime, and niche can indeed add value to the understanding of transformation in this new context (Wieczorek 2018). This becomes particularly clear when looking at digital technologies, which are increasingly setting disruptive processes in motion in the global South, while at the same time highlighting the tensions that already exist to a particular degree between individual economic-political and social structures. In the upper part of this article, we have therefore elaborated three arguments from development studies in relation to digital technologies. What are the most important findings from this research perspective for the MLP?

The gap between Niche and Regimes in the Global South can be complex on various levels. While many landscape developments favour increased Niche activity (e.g. access to ICTs, better accessibility of technological development frameworks, improved digital literacy, or financial capital for digital initiatives), Regime structures are often based on indigenous or traditional systems that have a very distant relationship to digital technologies. On the one hand, this has led to many voices promoting the idea of "leapfrogging" from little or no to cutting-edge technology use (Iyer 2018, Blimpo et al 2017); on the other hand, it illustrates the complexity of skipping over different discourse and adaptation processes that other sociopolitical structures have undergone. In the sense of an empowering process as envisaged by the Capability Approach, there is therefore the risk of a marginalization of non-technology-compliant social structures that lose their legitimacy due to a fundamentally lacking reference to digital technology itself. Or to put it another way: Bridging large gaps between Niche and Regime Level or leapfrogging do not refer exclusively to technological developments but can also develop immense frictional force in the course of social discourses and directional disputes in the global South. The possibility of freedom of choice that technology can enable is thereafter in danger of being only available to a specific group of Niche actors, who exploit the scaling potential of digital technology and thus also determine societal discourses.

Similarly, we want to highlight the distinctives of contextuality in digital production processes. It explicitly recognizes that social patterns in the design process find their way into technological structures and can thus directly change social structures. Contextual development in the sense of "on the ground" development is therefore intended to facilitate greater acceptance and fewer social disruptions in tense contexts. However, by facilitating digitalization through globally embedded

innovation hubs, technical discourses, and digital actors, a tense relationship between niche and regime emerges. By allowing global landscape developments to drive digital development in the niche while infusing social aspects into technology, there is a risk that contextual benefits will be negated. In order to challenge the existing socio-technical regime mechanisms that have emerged from diverse and long-standing social discourses, it is therefore particularly important to achieve a docking point that is as low-threshold as possible. Activities in the niche should be contextually close to local and regional social systems, which is, however, endangered by the strong global orientation of development processes in the digital sector. This again highlights the immense tension created by digitalization between regime and niche dynamics in the global South, and shows why in this context a nuanced, small-scale approach to MLP research is particularly important.

On an abstracted level and conclusively for the adaptation of MLP in the Global South, we see an important insight in the foreground: digital technologies enable niche actors to increasingly attack regime structures with the help of large scaling effects of technologies and increasing pressure from the landscape level. However, due to the large socio-cultural gap at both the production level and the application level, multi-layered problems arise that can be summarized by the perspectives on Justice (Benett et. al 2019). First, the multifaceted nature of existing socio-technical systems in the Global South must be adequately represented at the regime level. To do so, existing arrangements of participation and representation need to be analyzed in their complex diversity to understand the actual disruptive impact of new participation and representation dynamics through digital technology.

Second, the distribution of benefits is often only available to an exclusive part of stakeholders that, on the one hand, brings along the technological knowledge as preconditions of use, and, on the other hand, has been co-conceived in the inherent logic of digital technology (Seale 2011). In this sense, mere participation in a technological development per se says nothing about the quality of the benefits. When diffusing new socio-technical systems into the regime, the characteristics of the stakeholders in the niche should therefore not be simplified and standardized. Even if the stakeholders are initially held together by the desire for the dominance of new systems, a new order of the regime can lead to problematic unequal distribution of benefits within this group. The danger, therefore, is that digitally guided socio-technical system changes that push out of the niche into the regime do not eliminate grievances, but only upend the beneficiaries. The regime in the sense of a socio-technological system in the Global South should therefore not be understood as a consolidated entity, but as a consolidated diversity of many parallel established systemic structures. For the diffusion from niche to regime, this can ultimately also mean that new socio-technical systems - in our examples supported by digitization - can move not in a way that replaces but rather also complements existing

socio-technical systems. In our opinion, this aspect of the justice debate from development studies must therefore be taken into account in transformation research using MLP in the Global South.

5. Conclusion

The conceptual considerations in this article started where digital technologies, sustainability transformation and the existing complex tensions in the Global South meet. With the increasing establishment of MLP-led transformation research in the development context (Wieczorek 2018), there is a need to initiate a solid knowledge transfer in this obviously transdisciplinary field of tension. The presentation of basic findings of ICT4D research and their linkage to MLP shall therefore provide a first building block and basis for discussion regarding this very problem.

First, it should be pointed out that the bridging of niches into regimes via leapfrogging is not only related to digital technologies, but that actors and institutions also make immense leaps at the societal level. These do not necessarily proceed without accompanying conflicts. Second, development activities of digital technology should be contextually oriented as close as possible to local and regional social systems, so that the underlying characteristics of digital technology, which are dominated by global influences and thus from the outside, do fit the given context of the implementation. Third, participation, representation and the distribution of benefits should be consistently considered in the development and implementation of socio-technical systems, so that existing social systems and structures are complemented and not radically overwritten.

This article does not claim to generate a complete symbiosis of the MLP into the development context. Rather, three exemplary problem areas were pointed out and first conceptual considerations for overcoming them were presented. As a conclusion, it can therefore be emphasized once again that an ill-considered adoption of MLP into the development context is not advisable, but by linking it to existing concepts of development research, this new perspective on transformation can be quite profitable.

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5. Synopsis and outlook

This thesis started with the experiment of conducting interdisciplinary research in the field of digital innovation and their impact on social transformation processes in the Global South. The individual articles have each attempted to analyse from a specific perspective how this impact manifests itself and how the transformation processes can be illuminated both from a very practical, empirically observable point of view and from a theoretical point of view. Each article follows its own approach to research, which is reflected in the different underlying methodologies and theoretical frameworks.

What all the articles have in common is the approach that transformation processes through digitization are not to be understood from a problem-oriented (prescriptive) perspective (cf. Feola 2015). Rather, in the research design, emphasis was placed on conducting an accompanying analysis without evaluation based on the achievement of a goal and thus understanding the transformation process. Thus, this thesis does not provide insights into problems and solutions on the way towards a predetermined transformation goal. Instead, this dissertation shows how transdisciplinary methods and concepts from different scientific sub-disciplines can be used to better understand transformation processes. Or to put it differently: this thesis does not answer how a predefined goal can be better achieved by means of controlled transformation processes, but how the influences that lead to outcomes of ongoing transformation processes can be better understood. To conduct the actual research, this approach was narrowed down to the example of digital technology production environments in the Global South. This containment is based on two arguments: first, it complements the prevailing research landscape, which focuses predominantly on the implementation of technology in the Global South and thus gives very limited attention to the earliest stages of technological development. This focus on the production environment allows not only to analyse users, but also to look specifically at the drivers and transmitters behind the normative decisions of the developers and designers of a technology. Here the focus is on the aspect that technology can never be neutral and that not only its practical use but also its inherent characteristics are shaped by social influences. Second, it analyses the technological factors of emergence in interaction with the social embedding. As a result, the process of

emergence is not understood and mapped statically, but as a dynamic network process, which makes the theoretical conception, later design and subsequent production phase of new technologies scientifically analysable in a completely new way.

For the three individual articles, the theory of the multi-level perspective was of decisive importance, since it can deal with transformation processes in a sufficiently abstract and large-scale manner on the one hand, and in a detailed and concise manner on the other. The transformation processes triggered by new technologies and the accompanying social adjustments can be very well classified in the 'transitional struggles' between niche and regime. In the context of this work, so-called innovation hubs/networks were identified, which function as a relatively closed cosmos and play a crucial role in these contestation processes, as they often challenge historically grown and established structures (regimes) with their results. Thus, the object of research was not a selection of digital innovations, but their general development environment, which form the guardrails for contestations and can thus be conceptualized as a niche. Under the umbrella of globalization processes, fast-moving digital developments and a rapidly changing Global South, the last major level of MLP, namely the landscape, could also be incorporated into the analyses. Lastly, the extensive scholarly discourse around MLP, dealing with smaller-scale structural patterns such as legitimacy developments in the niche and the regime, offers a treasure trove of possibilities for deep detailed analysis which have proven very useful for this work.

Based on this derivation, this work has produced several results, which will be summarized below. First, the tangible results of the empirical investigations and conceptual developments that can be found in the three articles. Second, this conclusion will briefly discuss the experiences and learnings that emerged from the interdisciplinary approach (focus on production environment and the network approach) related to the overarching research question that ties the three articles together into a coherent repertoire. And third, as a resume, this work has generated new questions and open discussion points, which are listed at the end and placed in the overall context of the work.

5.1 The Articles

Starting with the three articles, the following tangible results, which are to be considered as the foundation of this dissertation, can be drawn from the research conducted.

Article I *Production Environments of Digital Innovations: a Scalar Perspective on Cultural Legitimacy in Zambian Coding Networks*

The first article was written on the basis of a case study and addresses the development of cultural legitimacy in the context of coding networks in Zambia's capital Lusaka. Here, attention was paid to the conception of frames that stakeholders in the production environment use as a basis for their development actions and that confer legitimacy on them. Three categories of legitimacy played a central role in the analysis: credibility, empirical fit, and macro-cultural resonance. These were analysed on the basis of scale and perceived plausibility, and thus constructed together into the frames mentioned above. The aim of this analysis was to gain a better understanding of the dynamics and working methods of coding networks and to be able to understand their outcomes (products and digital innovation) more consistently on this basis. The underlying argument is that understanding the social and technical structures behind new technologies is elemental to understanding the inherent properties of a digital technology itself.

First, three dominant frames for achieving cultural legitimacy can be identified from this case study: First, digital innovation, as a result of programming, is seen as an indispensable and elementally significant component of shaping and guiding the future. Underlying this frame is the worldview of technological determinism established in coding networks (Chandler 1995), which defines technology as an indispensable condition underlying the pattern of all social arrangements. The development environment of new innovations in the Global South thus defines itself as a powerful force that can significantly shape transformations of society and also actively strives to do so.

Second, the development of digital applications is defined as an imperative way to integrate Zambia into a perceived, well-established, global community of digitally active actors. This community is not only seen as a basic framework for economic and social development, but also has explicit positive connotations. Its core characteristics are

always problem solving by means of digital technology and the pursuit of implementing ideas that make the world a better place. Participation in this global network is seen as increasingly easy to achieve thanks to the availability of information on the subject of programming. Attention is also paid to low-threshold participation, which is made possible through online (e.g. open source contributions), or offline (e.g. meetups organized by tech corporations). The community aspect and becoming part of a larger whole is therefore a core component of the cultural legitimacy of stakeholders from coding networks.

Third, programming digital applications is seen as highly skilled work that enables self-determined career and life choices away from old and traditional structures of influence. Two factors play an overriding role here. On the one hand, the practice of programming is seen as high-skilled work that can only be performed by a small selection of talented people. This narrative, which is often constructed by the immediate environment, is often fuelled by the good job opportunities, which can also be exercised internationally through remote work, and very high salary ranges in relative terms. Last but not least, this status leads to the stakeholders' own understanding that work on digital technologies is more independent of legal structures and norms. The ability to program is therefore seen as the key aspect that decides between the constraint of having a 'normal', socially accepted and traditional profession and the participation in perceived international and modern job opportunities. The perception from execution of one's own agency, i.e. the ability to take the future into one's own hands, is therefore regarded as particularly high and desirable.

In addition, the case study also provided valuable insights into how these frames compare with the evaluation of the direct environment of the coding networks from the outside. Through the analysis of perceived plausibility and salience, it is clear that the technological determinist view in particular is strongly challenged by older and conservative actors outside the coding networks. Furthermore, it is clear that cultural reference points and community constructions are highly selective in terms of perceptions of Internet culture, which are often in stark contrast to offline situations.

Last but not least, the third article shows how the legitimacy of the actors from the coding networks can be derived from international influences rather than from the often more

sceptical local context due to factors of scale. Moreover, internal hierarchies can also be discerned in the development environments of digital innovations. Individual actors in these networks are in particularly prominent positions and act as 'scale facilitators'. This role allows them to filter international influences and spread them throughout the network with the help of their own legitimacy. The findings on these 'scale facilitators' then formed the basis for the research design of the second article, the core results of which are presented below.

Article II *Influence in Technological Innovation Spaces: A Network Science Approach to Understand Innovation for Sustainability in the Global South*

In the second article, innovation hubs from three different countries - namely Zambia, Uganda and Ghana - were examined. The focus was on their capabilities and attributes to build communities where new technologies are developed, tested and deployed. Furthermore, a focus was on their functions as networks that bundle, filter and disseminate new ideas around the topic of digital innovation. Based on large amounts of data from the social network Twitter (14,665 total unique users and 97,040 individual tweets), we investigated how ideas and concepts are bundled and disseminated within the innovation hub communities and whether it is possible to identify how the shaping of discourses manifests itself in practice.

The core result has shown how individual actors manoeuvre themselves into very significant and central positions in their innovation hub network through their function and actions. In doing so, they gain the ability to significantly steer and dictate the discussions surrounding the development and dissemination of new digital innovations. They gain this power through two influencing factors: on the one hand, through their international network, and on the other hand, through their own outstanding position within their own innovation hub community. Of course, both positions are mutually dependent. Accordingly, the key positions within the networks are not only very closely networked with their direct local peers, but also have contacts to other similar network institutions on the African continent, which influence them and, in turn, are influenced by them. This measured online communication can also be complemented by an offline

component, as the central positions are also statistically more likely than average to be connected to conferences and other similar networking events. Moreover, they - rather than the quantitatively larger players that make up the network of innovation centres - have been identified as the main target groups of highly influential innovation umbrella organizations such as AfriLabs. It can thus be definitively stated that the central actors form a kind of bridging function between international innovation stakeholders and their own local community. The findings on these super-positions and their occupation in innovation networks ultimately complement the concept of innovation intermediation. This concept of Friederici (2016), which refers to the assembly of previous distant innovation actors, is extended by the factor of the internationalization of innovation. Innovation networks not only bring together local/regional (in their cities, regions and countries) motivated and capable actors to work together on digital innovations, but rather feed these former distant actors into an established international network. The result, as the research shows, is a strengthening of the niche and greater opportunities/openings to penetrate regimes with their activities. Even though the research does not show any statement on the success of this penetration, it does illustrate the importance of the central network actors on the development process of digital innovations, which in turn has strong transformational significance.

As a second result of this research, we define the geographic concentration of network actors on urban areas. The analysis of the data shows that cities are significantly more important for innovation networks than their rural counterparts. Although the results are not surprising, the relatively weak representation of rural areas once again impressively demonstrates the importance of cities for the development of digital products. In addition, it was possible to identify individual significant hotspots that are recognizable in the data. For example, although not explicitly the subject of the research, the innovation centres around Johannesburg, Nairobi, Dar es Salaam and Lagos exert a strong influence on the innovation networks and have a very strong impact on the three hubs in Zambia, Ghana and Uganda.

Article III *Perspectives on Linking Digital Transformation to Sustainability Transformation in the Global South*

The third study of this dissertation addresses the conceptual level and discusses the potentials, pitfalls, and a selection of prior scientific work to be considered that are relevant when transferring the MLP to the development context. In the digitally led field of development research, the research field of Information and Communication Technologies for Development (ICT4D) has established itself as a central element. The distinctive feature of this field is the combination of new technologies and their application/development in the Global South, from which a solid understanding of these complex development processes and outcomes has emerged over the past decades. Most recently, however, several scholars from a different discipline, namely sustainability transformation studies, have approached the same research field of digital technologies in the Global South. Thereby it could be observed how many learnings from the ICT4D field either had to be redone or were unintentionally ignored. On this basis, the third article of this thesis starts by showing the advantages of the MLP-led perspective from sustainability transformation studies. However, the article also discusses some of the fundamental paradigms of ICT4D and makes initial transfers that show how both research perspectives combined can add value to understanding digital innovation and their impact on development and societal transformation processes.

In addition to a classification of digital and sustainability transformations in the Global South, the article begins with a quote from Wieczorek (2018: 210). In this, she describes MLP as an analytical framework to better understand the "bigger, systematic picture" of transformations in the development context. She goes on to explain that this perspective has not been sufficiently explored by development studies to date. In the article, this quote is taken as an opportunity to take a closer look at the broad findings from development studies and to show that the conscious small-scale and contextual view of development studies does not represent a blind spot, but rather follows a deliberate scheme. Underlying this schema is the approach that the socio-technological context is difficult to generalize and, due to the enormous diversity in the Global South, the big picture is often not considered to be useful for a better understanding of the processes. Thus, in order to use

the MLP sensibly for transformation studies in the development context, a transfer between disciplines is needed. This is done in the article on the basis of three exemplary but in scope representative debates.

First, participation in relation to digital innovations and, in particular, the capability approach will be presented. The core of the discussion is how digital technologies in the transition from niche to regime often generate large leaps in changes at the societal level through leapfrogging. Research in ICT4D has shown how this puts stakeholder participation at risk. Therefore, for the transferability of MLP to the development context, there is a need to analyse not only the transition of new practices and technologies into the regime, but also the consequences for stakeholders who either have to adapt or are completely excluded from the participation of new regime structures due to the immense differences. In this sense, it is important to understand that in the Global South, transformation processes often exacerbate, or redistribute, the inequality that already exists to a great extent.

For the second exemplary account of ICT4D debates, the article presents the relevance of contextuality. Against the background of social acceptance, it is first important to place the understanding of the 'user groups' of socio-technical systems at the centre of the analysis. Thus, a digital innovation is not necessarily used in the same way as it was envisioned and designed in the development process. In the ICT4D field, a large number of studies have been carried out on this subject, dealing with the effects of well-intentioned but incorrectly implemented digital solutions. The transfer of out-of-context socio-technological systems to environments in the Global South therefore often leads, on the one hand, to a lack of intended impact and, on the other hand, to the occurrence of undesirable and unforeseeable side effects. This is similarly illustrated in the second article of this dissertation using the example of production environments and innovation hubs. For the analysis of the niche within the MLP framework, this means that there is a risk that influencing factors from the landscape can be a disproportionately strong factors on local development processes. Equally, this influence can also come from other regime-niche relationships that are fundamentally different in structure because they come from elementally different development environments. A gap thus arises between contextual

application and the associated acceptance and correct handling of the technologies by the users and non-contextual influencing factors from the landscape or 'distant' regimes and niches.

For the third exemplary link between ICT4D and MLP, the article explores the justice debate. Here, we first discuss how existing participation systems in the regime distribute outcomes and how disruptive digital technology changes the quality of participation. For example, not every person can equally take advantage of the benefits of a new technology and accordingly receives unequal access to benefits per se. These benefits can range from participation to the direct effects of digital technologies such as economic or social improvements. Therefore, for scientific analyses in the Global South, it is important not to overgeneralize the niche and to understand the characteristics of stakeholders and actors on a small scale. Over-standardization and generalization of the niche, which MLP tends to do, can otherwise lead to reinforcements of power imbalances or to new constellations of inequality and injustice. Thus, in order to take into account the unequal power positions that are often disproportionately prevalent in the Global South, studies of new socio-technical systems must incorporate this aspect from the outset when diffusing them into the regime.

5.2 Tying the articles together

In addition to these findings from the three articles, this dissertation also adopted a unique approach that took an interdisciplinary path to answering the following overarching, somewhat more abstract research question:

"What is the influence of the production environment in the emergence of new socio-technical systems from the digital domain on social transformation processes in the context of the Global South?"

The question involves three core aspects. First, the focus on the production environment of digital innovation against a focus on implementation spaces. Second, the relationality of this environment in terms of networks, which is analysed through a relational scale concept. That is, the development environment is not understood as a static entity, but as

relational processes that only acquire meaning through the connections between actors and interactions with technologies. And third, not only the influence of the production environment on transformation processes themselves, but in the same relational sense, a focus on influences that shape and form the production environment itself.

While the empirical results of the three articles summarized above thus approach the 'substantive' answer to the research question, this chapter will additionally summarize the extent to which the attempt to answer the central research questions has also produced results at the conceptual level. In the course of the research, three overarching aspects have emerged, which will be explained hereafter:

> 1) Through a better understanding of the production environment of digital innovation, new insights into its role in ongoing social transformation processes can be obtained.
>
> 2) The relational space conception of production environments as networks enables a sharpened view of their role in transformation processes, which could not be sufficiently considered in a static approach.
>
> 3) Scale concepts, which allow to analyse deeper connections between individual actors and processes within the production environment, provide new insights into driving forces behind the dynamic, ongoing and fluid formation of production environments.

To begin with, this work has deliberately chosen the approach of not looking at concrete technologies and their impact on social transformation processes. Instead, the products were conceived as abstract digital innovations whose development environment was to be the focus of attention. In doing so, it became apparent that in order to analyse and understand socio-technological transformations, the production environment is an important piece of the puzzle in the overall understanding of a socio-technological transformation in the Global South. Specifically, the findings of the first two articles were used to show how the actors behind the creation of new innovations bring their social backgrounds, characteristics, and biases into the production process. This influence ranges from the idea phase, to the concrete design, to the selection of technological tools.

The finished product thus always reflects the producer in a fundamental way. The MLP framework has also shown how production environments initially form isolated niches within which digital innovations can mature in a protected atmosphere. On the one hand, this isolation creates legitimacy and thus a protected atmosphere for development, but it also leads to conflict-laden processes in the efforts to create new regime structures. Thus, starting from socio-technical systems that fulfil a specific social function, showing the importance of the production environment also allows us to see where the conflicts in regime contestations stem from. Without this perspective, this second level, i.e., the reasons behind a new socio-technical system design, would not be discernible in this depth. Thus, this work has not accompanied a concrete transformation process, including its concrete conflicts. Rather, it provides a starting point for upcoming studies on digitally induced transformation processes in the Global South through the background listed in the articles on the characteristics and peculiarities of the "producers" of new socio-technical systems. Looking at historical, or currently existing, production environments would provide a snapshot, but would not allow complex and necessary conclusions to be drawn about the emergence of socio-technical systems and the digital innovations that accompany them. Since the designs of digital innovations are dynamic processes, as demonstrated, this work has shown the added value of the network idea for the design of production environments as a second overarching insight. Accordingly, the object of research in the form of innovation environments of digital technologies in the Global South cannot be attributed to definable areas of a map or delimitable physical environments. Instead, it consists of relationships between the actors involved in the innovations and their foundations, as well as technical structures that determine these interconnections. Herewith this work adapts a relational space definition from geography.

Thus, when approaching the answer to the question of "how" to influence the production environment on transformations in the Global South, networks play a central role according to the findings of this research. In this sense, networks mean that actors do not realize their ideas, visions, and implementation strategies in the development of new technologies in isolation, but in interaction with other actors, institutions, and available practical resources (e.g., technical frameworks, funding opportunities, educational opportunities, etc.). Especially since the processes of technology development including

their testing environment in the niche are not uniform or standardized in time, the connections and reconstruction of influences within the network are an appropriate approach to better understand the real reasons behind newly developed socio-technological systems.

In the methodological area, this thesis has worked from two perspectives: on the one hand, the observation and analysis of a network from a classical social science perspective (observations, interviews, etc.), and on the other hand, data gathering and analysis by methods of computational social science (data from social networks and algorithm-based evaluation). What both have in common is the lack of a claim to completeness. It shows from the experience of this dissertation that it is possible to describe networks in their dynamic form and to draw conclusions about the influences behind socio-technological transformations.

Since it has become clear throughout the research design that network analyses have no universal standard, and that the details are complex and dependent on the problem or research questions or hypotheses, the final overarching finding of this paper relates to the theoretical framework of Scale. By transferring scale concepts to the production environments of digital innovations, a theoretical framework of analysis was created, the consideration of which made an in-depth analysis of the production environments of digital innovations possible in the first place. From a simple network analysis that provides only superficial information, the scale approach thus gives new depth to the question of influences. This is centrally due to the fact that, against the background of their available access and social embeddedness, the individual entities of a network are endowed with different ranges and levels of knowledge. This ambivalence of individual network nodes and edges, which has manifested itself through research, culminates in a central insight: when actors and institutions possess influence over network actors outside of that geographic location through their geographically located actions, no hierarchical scale concept can be applied. Thus, it is not hierarchical chains of influence that apply, but diversified, decentralized, and non-obvious structures that must also be conceptualized as such for a scientific debate. In relation to the research object of this thesis, this means that digital technologies cannot emerge locally, or in the context of a specific

geographically defined area. Rather, they are per se shaped by influences that can only be observed through relational networks and a relational scale understanding. For research practice this means: Categories such as local, regional and global, government, institutions and individuals should not be generalized as influencing factors in the context of production environments. Rather, they should be understood in relation to their position within a network. Against this backdrop, network nodes (e.g., a government institution) from geographically distant locations can therefore exert a more significant influence on a production environment of digital innovations than a node that is physically closer, has more cultural similarities and may even be seemingly more actively involved in the development process itself.

5.3 Outlook

If the research on this thesis has shown one thing, it is this: the complex interrelationships between technological innovation and social transformation in an already tense environment like the Global South cannot be conclusively explained. Even within a deliberately well-defined and delimited research subject, such as the innovation networks in Lusaka, or the three selected hubs in Zambia, Ghana and Uganda, the limitations of the methodology and the size of associated transformation processes quickly became clear. The same applies to the intended combination of two established disciplines, such as ICT4D and sustainability transformation studies, and the methodological interdisciplinary approach. For every analysis, for every insight, new questions arise. Rather, this work has therefore hopefully been able to contribute a small building block to the overall picture. Naturally, research leads to more questions than it is possible to find answers to. Accordingly, the following is an outlook on three new questions that can be derived directly from this dissertation.

First, the problem of the detailed integration of the landscape into the basic framework of the influence debate around relational networks and relational scale conceptions. Even though the MLP level of landscape has already been partially incorporated into the analysis in the case studies, its full significance for production environments has not yet emerged in this work. The central question here is to what extent factors originating from the landscape, such as market mechanisms, natural changes like climate change, or

geopolitical factors can be integrated into the relational space and scale concept of this work.

Second, the need for further research in the area of detailed MLP theories, which, similar to the theory of cultural legitimacy used in this thesis, can bring significance to the better understanding of production environment and its influences on transformation processes. Whenever new socio-technological systems are worked on in the niche, novel complex technological and social structures and strategies emerge to lift them into the regime. It is not without reason that the scientific field of Sustainability Transformation is subject to constant growth. New theories and frameworks of understanding of ongoing transformation processes can be well applied to the research subject focused on in this thesis. Two obvious theories would be, for example, the ongoing debate on the influence of governmental policies (e.g. Rogge et al. 2020), or the integration of theories on narrative development and its relevance for MLP (e.g. Hermwille 2016).

And third, the question of a methodological development from the field of computational social sciences. Especially in the area of graph and network analysis, this work has only scratched the surface. The algorithms used to analyse network data represent only a small subset of the available tools, which are particularly useful in the area of influence analysis, but also in the area of information flow analysis (via which edges does information reach certain nodes?), or in the area of attribute acceptance (which included information manifests itself in attributes of nodes, in which form are they accepted, and why does some information leave effects while others are ignored?).

The aim of this work was not a complete analysis of production environments of digital innovations in the Global South and their influences on transformation processes. Rather, it was intended to open the door to two important perspectives. First, for a broader view away from prevailing rigid implementation scenarios of technologies towards the importance of production environments on transformation processes. On the other hand, to a relationally oriented conception of influencing factors that make these very production environments what they are: dynamically functioning networks that should not be considered without the multitude of constant influences around them.

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