Research Policy 52 (2023) 104672

Contents lists available at ScienceDirect

Research Policy

journal homepage: www.elsevier.com/locate/respol

Social movements and institutional entrepreneurship as facilitators of technology transition: The case of free/open-source software

Sanjay Jain [a,*], Habib A. Islam [b], Martin C. Goossen [c], Anil Nair [c]

[a] Department of Management, Nazarian College of Business and Economics, California State University, Northridge, 18111 Nordhoff Street, Northridge, CA 91330, USA
[b] Schools of Business & Accounting, Eastern Washington University, Spokane, WA, USA
[c] Department of Management, Strome College of Business, Old Dominion University, Norfolk, VA, USA

ARTICLE INFO

Jel classifications:
B520
L17
O33
O36

Keywords:
Technological regimes
Multi-level perspective
Strategic niche management
micro-histories
Social movements
Institutional entrepreneurship

ABSTRACT

We integrate insights from the literature on social movements and institutional entrepreneurship into the strategic niche management (SNM) and multilevel perspective (MLP) frameworks to understand the emergence of Linux, a free/open-source operating system, in a regime dominated by proprietary operating systems such as Unix and Windows NT. Employing a "microhistories" methodology, we document how actors in the free/open-source movement took steps that enabled an alternate technological niche to form, gain momentum and eventually infiltrate the extant regime. Our account delineates the key role that actors play in *shaping* the identity of a niche, *amplifying* its presence, and finally *mainstreaming* it. We observe a heterogenous response by incumbents to the emergent niche and highlight the *sustained coexistence* of a niche and regime as a distinct form of technological transition. Finally, we demonstrate the significant impact that a niche can have, spanning beyond the targeted regime, and becoming part of the landscape. Our insights highlight how tracing the processes involved in the emergence and development of a niche can provide a prospective and generative understanding of technological transition, thereby contributing to and complementing the extant SNM and MLP literatures.

1. Introduction

Ever since Schumpeter coined the term "creative destruction" to describe how innovation was a key driver of industry dynamics, there has been much discussion on the role played by new entrants in facilitating this process (Schumpeter, 1942). Schumpeter referred to these actors as entrepreneurs, who challenged and transformed existing economic structures through endeavors that typically involved combining existing and new knowledge. Subsequent literature has emphasized the systematic limitations that incumbents encounter in responding to architectural and disruptive innovations (Christensen and Bower, 1996; Henderson and Clark, 1990), thereby enabling newcomers to enter and become prominent players in an industry. More recent scholarship has highlighted the dilemmas that newcomers face when attempting entry into an industry (Ansari et al., 2016). These findings are a testament to the ongoing interest in understanding the role of these actors and the related dynamics that unfold as part of technological change.

In parallel, the multilevel perspective (hereafter referred to as MLP) has emerged as an influential viewpoint for describing technological transitions (Geels, 2002; Markard and Truffer, 2008; Smith et al., 2010). This framework posits that socio-technical regimes are comprised of a set of complementary and mutually reinforcing technologies, with their associated rules, norms, and understandings, that collectively serve the market. The regime is itself embedded within a larger landscape, whose societal, economic, and engineering demands determine the requirements for, and perceived performance of specific technological systems. At the micro-level, novel technologies, different from those that constitute the regime, are developed within niches (these are the newcomers within the MLP framework). Through a process of improvement, the development of complementary assets, and the crafting of related institutional elements, a niche technology can invade the regime. These transitions are typically made possible through changes in the landscape where sudden shocks or changed socio-economic preferences weaken the lock-in of the existing regime and provide the conditions that make growth and adoption of the niche technology more likely (Geels, 2002). A related stream of literature, strategic niche management (SNM), examines how radically different technologies come into existence (Rip and Kemp, 1998). According to this scholarship, market niches emerge when specific groups of users are not served well by the existing regime, i.e., the needs and evaluation criteria associated with these spaces are

* Corresponding author.
E-mail addresses: sanjay.jain@csun.edu (S. Jain), hislam@ewu.edu (H.A. Islam), mgoossen@odu.edu (M.C. Goossen), anair@odu.edu (A. Nair).

https://doi.org/10.1016/j.respol.2022.104672
Received 16 January 2021; Received in revised form 19 October 2022; Accepted 14 November 2022
Available online 24 November 2022

significantly different from those of the regime. This provides opportunities and incentives for actors to develop innovations better suited to the niche's needs (Turnheim and Geels, 2019). Moreover, actors take steps to isolate and detach the niche from the regime, providing protective space for these innovations to develop (Smith and Raven, 2012). Over time, these alternate technologies gradually improve and diffuse into larger market niches, even as they encounter resistance from the regime and the incumbents entrenched within it.

While both the MLP and SNM literature have yielded useful insights, they are rooted in an evolutionary economics tradition and tend to emphasize an "outside-in" perspective of the dynamics involved in technological transitions: one that details outcomes in terms of macro-patterns (Geels, 2020). On this front, there have been calls for scholarship that takes a complementary approach and adopts an "inside-out" ontology that captures the 'generative' forces associated with these transitions (Farla et al., 2012; Smith and Raven, 2012). Such an approach would likely provide a more detailed portrayal of the actors involved in niche formation and development. Moreover, it would highlight the interplay of cognition and action that unfolds during the emergence and evolution of radically new technologies, detailing the collaborative, contested, and convoluted paths that these innovations often take (Garud et al., 2002; Jain, 2020).

In this paper, we endeavor to develop such an "inside-out", actor-centric and generative account that provides complementary insights on how newcomers craft these novel spaces and subsequently navigate their innovations towards mass acceptance. We do so by incorporating insights from the literatures on social movements and institutional entrepreneurship. Social movements are described as "sustained challenges to a higher-level authority or institution by individuals and organizations affected by that authority through continued acts of protests that display the movement's power and force" (Tilly, 1993, p. 7). These are initiated by individuals or groups who envision the need for institutional change to address a problem and then take actions consistent with these intentions (Hargrave and Van de Ven, 2006). In this study, we build on these ideas and suggest that niche dynamics can be gainfully understood as a social movement involving acts of institutional entrepreneurship. From this perspective, alternative technologies are embedded in a unique socio-political context, and their ability to develop as viable niches is strongly influenced by individuals and interest groups whose objective is to facilitate the introduction and growth of these alternatives (Jain and George, 2007; Sine and Lee, 2009). By joining forces with other interested actors and gradually gaining momentum, these niches can (sometimes) come to possess the collective energy required to enable technological transition. Tracing the emergence and development of niche technologies as a social movement, then, can provide us with a more grounded explanation of the processes unfolding as part of such migration, thereby contributing to and complementing the extant MLP and SNM literature.

We employ an in-depth, historical account of the emergence of the Linux operating system as an alternative to the dominant proprietary software regime, to illustrate this perspective and develop our insights. Our narrative emphasizes the key role that individuals play in *shaping* the contours of a technological niche, in particular its identity. We demonstrate how actors *amplify* a niche via such activities as coalescing as well as establishing entirely new interaction architectures and practices. We also specify how actors are involved in *mainstreaming* a niche such that it is more understandable and acceptable to members of the regime. We highlight the *sustained coexistence* of a niche and regime as a distinct form of technology transition and find that the ideology associated with a niche can have a substantial impact that extends to the larger landscape. In articulating these findings, we advance current theorizing related to niche dynamics in the SNM and MLP literature as well as expand our understanding of social movement and institutional entrepreneurship processes taking place within high technology settings. Moreover, in locating our study within the operating system software sector, we extend the SNM and MLP frameworks to contexts beyond sustainability transitions.

2. The role of niches within the SNM and MLP literature

The SNM literature describes niches as protective spaces where newcomers develop radical novelties that are sheltered from mainstream market selection pressures (Schot and Rip, 1997). As an example, Smith and Raven (2012) explain the development of solar energy by pointing to space exploration's needs for a sustainable energy source. They go on to identify three processes that ensure that a niche remains viable: shielding, nurturing, and empowerment. Shielding involves ensuring that the niche is reasonably isolated from the main markets so that newcomers and their activities are protected from the selection pressures associated with the prevailing socio-technological regime (Hoogma et al., 2002; Raven, 2006). This scholarship makes the distinction between passive niches which are generic protective spaces that pre-exist (based on unique geographic, institutional, or user conditions), and active niches that are strategically crafted by advocates of specific path-breaking innovations (these include policy measures and incubator units). Nurturing refers to the interactions between visions and expectations, social networks, and learning processes that support the development of radical innovation (Kemp et al., 1998). Sequences of experiments and demonstration projects enable recursive cycles of these processes, which can generate innovation trajectories (Geels and Raven, 2006). The specific shape and character of these trajectories are influenced by the quality, specificity, and robustness of expectations, the depth and breadth of social networks, and the relative emphasis on first- or second-order learning (Schot and Geels, 2008a). Finally, empowerment refers to efforts to increase the strength or competitiveness of a niche (Smith and Raven, 2012). Here, Raven et al. (2016) make a distinction between "fit and conform" empowerment, which they define as processes that make a niche innovation competitive within unchanged selection environments, and "stretch and transform" empowerment, which refers to processes that restructure selection environments in ways favorable to the niche. Schot and Geels (2008b) further describe the tension within a niche between promoting reflexivity and adapting to the incumbent world.

While SNM focuses on the dynamics within a niche, a parallel literature stream, MLP, provides a nested, contextualized view of technology transition by highlighting activities taking place at three different levels: niches, which are the locus of radical innovation, technological regimes which are maintained and reinforced through lock-in mechanisms, and the wider socio-technical landscape that comprises deep structural trends, which are even more difficult to change, and are exogenous to both regimes and niches (Geels, 2002). Under normal conditions, the path-dependent, co-evolutionary lock-ins that characterize regimes (Dosi, 1982; Nelson and Winter, 2002) sustain incremental innovation that maintains the status quo (Geels, 2010). However, in certain situations, technology transitions are facilitated by an interactive process taking place across the three levels (Geels, 2002). First, experimentation with novel technologies in niches results in the emergence of robust alternatives to the existing regime (Rip and Kemp, 1998). Second, existing technological regimes are upended when changes in the broader socio-technical landscape remove interdependencies among technological components or invoke a reconsideration of the performance metrics associated with the regime (Jørgensen, 2012). This combination of niche growth and changing landscape allows novel technologies to move out of the margins and (potentially) replace an extant technological regime (Geels, 2002). Such a pattern of technological transition has been reported in sectors related to public infrastructure and renewable energy (Köhler et al., 2019; Markard and Truffer, 2008).

MLP also describes the multitude of ways in which radical technologies developed in a niche interact with the regime. In one scenario, the niche innovation is picked up by regime actors at a very early stage to solve a particular problem, and subsequent learning processes lead to changes in routines, behaviors, and practices by these actors and the

reconfiguration of technologies within that regime (Geels and Schot, 2007; Raven, 2006). In another situation, changes in the landscape create strong pressure on the regime that enables niches to gain momentum and results in the eventual replacement, or *substitution*, of the extant regime. This suggests the presence of multiple transition pathways for a niche (Geels and Schot, 2007).

While the MLP and SNM literature have yielded useful insights, prior scholarship has largely been based on an evolutionary economics microfoundation. Indeed, Smith and Raven (2012) note that the SNM conceptualization of niches as being functional in evolutionary terms fits with a more managerial 'outside-in' ontology, and runs the risk of not being able to capture all of the 'generative' forces required to initiate and then sustain these functional processes (Garud et al., 2010, p. 761; Smith and Stirling, 2007). Along these lines, empirical research has demonstrated that ideas for how niches ought to operate as protective spaces soon encounter confounding and conflicted realities (Geels and Schot, 2007; Lovell, 2007; Voß et al., 2009). In a similar vein, Geels (2020) suggests that the MLP has largely invoked a macro, 'outside-in' orientation to explain how transitions take place. In doing so, it has been less attentive to the role of actors, the strategies they enact to foster such transitions and the microprocesses that unfold as part of this interaction (Geels, 2020). In this paper, we build on these observations and indicate that theorizing related to the dynamics of technology transitions (as invoked by SNM and MLP) needs to be complemented with an 'inside-out' ontology that emphasizes the embedded agency of actors involved in niche construction and regime reproduction (Garud et al., 2010; Smith and Raven, 2012; Smith and Stirling, 2007; Zietsma and Lawrence, 2010). Such an approach would emphasize the cognitions and actions involved in initiating, sustaining, and (potentially) institutionalizing these "hopeful monstrosities" (Mokyr, 1990). Developing a prospective perspective that highlights the socially constructed roots of technological transitions and focuses on the contested and convoluted nature of this process, would add to our understanding of niche and regime dynamics.

3. A social movements and institutional entrepreneurship lens on technology transitions

To do this, we draw on the literature of social movement theory (SMT) and institutional entrepreneurship to develop our theoretical insights. SMT has described how small groups of actors change organizational, sectoral, and societal practices through drawing attention, leading discussions, and providing alternative solutions to relevant issues (Cornelissen and Werner, 2014). These movements are aimed at correcting specific social, political, or economic injustices and are driven by an ideological interest. They provide an alternative vision of existing issues – via the provision of more or different information – that is aimed at convincing the wider public about different modes of action (Benford and Snow, 2000; Cornelissen and Werner, 2014).

Social movements require creating or altering *cultural frames*, i.e. "schemata of interpretation" (Goffman, 1974) that are intended to attract potential supporters' attention towards the movement (Williams and Benford, 2000). Put differently, framing involves a process of meaning production that enables movements to identify and organize their experience in forms that help them connect to more powerful narratives (Snow et al., 1986) as well as inspire and legitimatize the activities that they engage in (Benford and Snow, 2000). Social movements also create and manipulate *political opportunity structures* (Meyer and Staggenborg, 1996), which refer to "vehicles, informal as well as formal, through which people mobilize and engage in collective action" (McAdam et al., 1996, p. 3). These structures pool individual inputs and aggregate them towards initiatives aimed at creating a new institutional order. And finally, to reform the existing regime in a meaningful way, actors also need to mobilize tangible and intangible resources, including capital, labor, connections, and legitimacy (Edwards and McCarthy, 2004). Such *resource mobilization* typically includes support from groups that provides a material benefit (McCarthy and Zald, 2001) as well as conscientious constituents who support it on the basis of some latent ideology (McCarthy and Zald, 1977).

More recently, scholars have highlighted how the evolution of technological innovations can be gainfully examined by employing a social movement lens (Elzen et al., 2011; Garud et al., 2002; Hargrave and Van de Ven, 2006; Hess, 2005; Kling and Iacono, 1988; Smith et al., 2016). Pioneering research by Kling and Iacono (1988) has suggested that the adoption of computing technology in the United States was not simply a product of economic forces, but also a function of 'computerization movements' whose advocates communicated key ideological beliefs about computer-based systems as instruments fostering a new social order. These scholars employ Blumer's (1969, p. 8) description of social movements as "collective enterprises to establish a new order of life" and emphasize activist entrepreneurs who help drive movements through books, speeches, and other actions. To them, computerization movements were built around technological action frames (Bijker, 1997) that describe the socially constructed meanings ascribed to specific technologies, "tying together relevant social actors and the particular ways in which they understand a technology as 'working'" (Hara and Rosenbaum, 2008; Iacono and Kling, 2001, p. 99). Hess (2005) has defined technology- and product-oriented movements (TPMs) as mobilizations of civil society organizations, for which the target of social change is support for an alternative technology and/or product, as well as the policies with which they are associated (see also Pacheco et al., 2014). The modus operandi of TPMs involves less emphasis on the politics of protest and more on building and diffusing alternative forms of material culture. More recently, in employing the literature on social movements to the politics of sustainability transitions, Hess (2018) draws attention to the opportunity structure for policy reform, the efforts of movement actors to build coalitions, and the importance of frames and cultural repertoires to gain support for their agenda (see also Pesch et al., 2017).

A related stream of research, grassroots innovation movements (GIM), examines how networks of people respond to the local environment and the interests and values of the communities living in them to generate bottom-up solutions attentive to their needs (Smith et al., 2016). According to these scholars, GIMs are informal initiatives that include a diversity of social actors, among them non-governmental organizations (NGOs), community members, and cooperatives. They employ alternative strategies of knowledge production, often directing their attention towards topics and issues neglected by conventional innovation initiatives. In originating different pathways of sociotechnical development, they raise questions about technological needs in a society (Seyfang and Haxeltine, 2012), appropriate directions of technological change as well as ownership and access to a technology (Smith, 2005). While these features imbue GIMs with a character that closely resembles social movements, it is important to emphasize that the former are centrally focused on strategies of knowledge creation and alternate pathways of knowledge and development (Hargreaves et al., 2013; White and Stirling, 2013). In their exploration of six case studies, spanning a diverse set of initiatives across many nations, Smith et al. (2016) highlight how GIMs emerge to promote local innovation and empower communities. A major dilemma that these movements face relates to whether they should insert themselves into prevailing institutions for innovation, or seek to mobilize support for transforming those institutions.

Finally, Hargrave and Van de Ven (2006) have highlighted how scholars in the technology innovation management and social movement theory literature, while historically operating independently, have reached strikingly similar conclusions about processes of institutional innovation. According to them, the major contribution of this convergent scholarship is the development of a collective action model that explains change as emerging from a dialectical process. This research views institutional change as involving framing contests, in which opposing actors, each seeking to achieve their goals, struggle against one

another to shape the meanings of relevant issues and technologies. It calls attention to the purposive efforts of institutional entrepreneurs (DiMaggio, 1988; Garud et al., 2007; Hargadon and Douglas, 2001) who construct networks of complementary players that collectively possess the skills and resources needed to enact the institutional arrangements that govern action. Finally, it suggests that the process of institutional change is a political process of mobilizing campaigns to legitimate a social or technical innovation (Garud et al., 2002; Jain and Ahlstrom, 2021). In these scenarios, the leaders of the movements typically demonstrate social skills and political savvy in understanding the interests of the other players in the network, as well as framing the change agenda in ways that appeal to the identities of these actors (Fligstein, 1997).

These disparate strands of scholarship highlight how the underlying mechanisms identified within the social movements and institutional entrepreneurship literature – i.e., cultural framing, creation and manipulation of political opportunity structures, resource mobilization, and institutional innovation – can be gainfully employed to understand processes of technological change in a multitude of contexts. However, the findings from these studies have not been integrated back into the SNM and MLP domains (Elzen et al., 2011 is a rare exception). One task of our paper is to address this lacuna. Specifically, we draw on constructs from the social movements and institutional entrepreneurship literature and employ them in our historical case narrative to develop concepts and insights that extend our extant understanding of technology transitions. We elaborate on our theorizing in the sections that follow.

4. Research design

We adopt a naturalistic mode of inquiry where insights are developed through interpretive means (Lincoln and Guba, 1990). We take the position that niche-related dynamics are best understood by providing "microhistories" (Hargadon, 2015) or "thick" descriptions of the phenomenon as it unfolds (Geertz, 1973).[1] Such a process-tracing approach is useful for investigating complex temporal phenomena (Jain and Sharma, 2013; Langley et al., 2013). In presenting detailed and historically grounded material, we endeavor to broaden existing theory and generate new insights (Lee, 1999). Our inquiry mode emphasizes "procedural adequacy" and "credibility" (Lincoln and Guba, 1990) that we establish by utilizing steps that Miles and Huberman (1984) suggested in their treatise on qualitative research.

Theory building in this tradition requires the selection of "strategic research sites" that capture integral aspects of the theoretical phenomena under examination (Bijker et al., 1987). Moreover, in conducting such studies, care needs to be taken to ensure that the findings are generalized in an analytical rather than statistical sense to other contexts (Eisenhardt, 1989; Glaser and Strauss, 1967). We chose the free and open-source movement within the operating systems software sector as our research site. This is a particularly pertinent domain to study as it is a central element of the infrastructure on which the digital economy is built (much in the same way as energy, water and transportation are infrastructural technologies of the physical economy). Specifically, our narrative account highlights the historical evolution of this movement from its emergence as a niche in the early 1980s to its presence as part of the regime by the early 2000s. This scope and time frame enable us to both "zoom in" to the motivations and strategies of specific actors (both individual and collective) within the movement as well as to "zoom out" and trace the impact of these actions on the larger technological domain. In doing so, it enables us to specify the underlying processes that have propelled this niche into the regime and generate insights that expand existing SNM and MLP theory.

Data for our analyses were obtained from multiple sources to identify the chronology of events as well as develop detailed descriptions of how events unfolded. We began by searching all the major business databases (e.g., Lexis/Nexis, ABI Inform, and Business Periodical Index) using the keyword search terms 'operating systems', 'proprietary', 'Linux', 'open source' 'free software', 'copy-left' and 'software' to obtain published information on the operating systems segment of the software industry. We added new search keywords as we read the literature about this sector. As the business and technology media (e.g., Wall Street Journal, PC Magazine, Wired, and Cnet.com) have covered the operating system field extensively, there was abundant information in the public domain that we leveraged to develop a detailed narrative of the free/open-source software movement. Articles in peer-reviewed journals as well as case studies written about this phenomenon were also referenced as part of assembling our dataset. Finally, we read over ten books written by industry experts and academics that aided us immensely in bolstering our narrative. Collecting data from these multiple data sources enabled us to achieve "triangulation" (Jick, 1979) as well as establish a deep familiarity with the details of the events that transpired relating to the emergence and evolution of this software niche. Moreover, we took steps to limit potential hindsight bias by relying on statements made and descriptions provided as the events themselves unfolded.

Poole et al. (2000) suggest that in order to explicate the processes underlying niche dynamics, one requires a narrative that relates the sequence of events as they unfold over time. In preserving chronological flow, such an account enables us to gain a better grasp of which events led to consequences, allowing us to make stronger statements about causality. Proceeding from this principle, we constructed a timeline of events from our archival effort (see Table 1) and used this to generate a qualitative account that provided a condensed but "thick" description of the flow of events associated with this niche.

Even as we developed our descriptive account, we remained cognizant of the theoretical issues and constructs that emerged. Through ongoing discussions and numerous iterations, we generated and explored tentative constructs that appeared to capture the dynamics that were unfolding within this sector. We subject our exploratory theoretical frame to the scrutiny of the continual data stream in order to actively modify and abandon its elements as well as add new elements as appropriate. We went through three major revisions of our theoretical framing before settling on the one developed in this paper.

Once we did this, we organized our description around the sensitizing concept (Corbin and Strauss, 1990) central to our study – i.e., the social movement and associated acts of institutional entrepreneurship related to the emergence of the free/open-source software niche. Here, we used theory and concepts developed in prior studies (Benford and Snow, 2000; Cornelissen and Werner, 2014; Garud et al., 2002; Hargrave and Van de Ven, 2006; Jain, 2012) to specify the main categories of analysis that we were interested in: cultural framing, political opportunity structures, resource mobilization, and institutional innovation. Next, we reexamined our data to uncover details of the actions related to these categories. This enabled us to craft a more detailed and integrated account of how actors engaged in these activities. In turn, we employed our narrative to inductively develop the theoretical categories of *shaping*, *amplifying*, and *mainstreaming*, which represents one of the key insights of this study. In addition, we discerned patterns and insights from our case – ones that we refer to as the *heterogeneous response* of regime actors, the *coexistence* of the niche with the regime, and the *span of influence* of a niche[2] – that, we believe, represent further contributions to the extant MLP/SNM literature. We then did one more extensive rewrite of our narrative, which was now expressed in the theoretical terminology that we had developed. These steps reflect the process of

[1] A thick description of a social event or action takes into account not only the immediate behaviors in which people are engaged but also the contextual and experiential understandings of those behaviors that render the event or action meaningful (Grandy et al., 2010).

[2] We thank our reviewers for identifying this pattern and suggesting this insight.

Table 1
Timeline of key events in the free/open-source movement.

Year	Events
1969	Unix developed at Bell Labs. Founders freely share source code (without support).
1974	MITS develops the Altair, the first personal computer; used by hobbyists for gaming
1975	Bill Gates and Paul Allen start Microsoft, write Basic for the Altair.
1976	Bill Gates writes open letter on software piracy.
1982	Anti-trust consent decree leads AT&T to withdraw free sharing of Unix code.
1984	Richard Stallman quits job at MIT's AI lab to start working on the GNU project.
1985	Stallman launches FSF. GNU Manifesto released: proposes the need for free software.
1986	Stallman uses GNU EMacs license to create first iteration of the GNU General Public License (GPL)
1987	Andrew Tannenbaum publishes text on operating systems; includes copy of Minix.
1989	GNU releases Version 1.0 of GNU General Public License
1991	Linus Torvalds announces his kernel project on a Usenet group. First version of the software. 0.01, becomes available. Ari Lemke uploads the code to a directory named put/OS/Linux. The name sticks.
1992	Linux Usenet group launched. Linux relicensed under GNU GPL. GNU newsletter mentions Linux for the first time.
1993	Linux version that supports networking released. Matt Welsh issues Linux Documentation Project Manifesto to collaborate in all issues of Linux documentation.
1994	Linux 1.0 debuts. Ian Murdock launches Debian GNU/Linux distribution. Marc Ewing releases first version of Red Hat Linux
1995	Apache web server project started.
1996	Linux Kernel version 2 released. GNU endorses Linux as a kernel. Kool Desktop Environment (KDE) project announced.
1997	Eric Raymond presents paper, The Cathedral and the Bazaar, at Linux Kongress and outlines the principles of 'open source' method.
1998	Netscape announces plans to open up the source of its web browser. IBM, Compaq and Oracle announce support for Linux. O'Reilly organizes meeting where the term open source is adopted as an alternative to free software. Bruce Perens and Eric Raymond found Open Source Initiative (OSI). Eric Raymond releases the "Halloween Documents".
1999	Linux 2.2 released. Red Hat and VA Linux have their IPOs.
2000	IBM announces investment of $1 billion in Linux development. OSDL founded to accelerate its deployment.
2002	Linux distributors Caldera, SuSE, Turbolinux and Connectiva sign an agreement to jointly develop a Linux distribution for servers.
2003	SCO files lawsuit against IBM for support of Linux. Novell acquires SuSE. Linux 2.6 released.
2004	Ubuntu Linux released.
2007	Open Handset Alliance (OHA) launched by Google and other vendors. Uses Linux kernel in their mobile operating system, Android.
2008	New York Stock Exchange uses Linux for its operating system
2011	Google introduces Chromebook computers which use Linux. Microsoft becomes the fifth largest code contributor to Linux.
2012	Data and software start moving to cloud. Most clouds run or support Linux, including Microsoft Azure. Open source company Red Hat achieves $1 billion valuation
2014	Microsoft CEO praises Linux; company adopts it for internal use
2019	IBM acquires Red Hat for $34 billion — its costliest acquisition to date

iteration between theory and data that took place until our narrative adequately captured developments in this domain and our theoretical frame and its underlying generative mechanisms were specified (Corbin and Strauss, 1990; Tsoukas, 1989). Put differently, our analysis involved converting descriptive historical accounts into analytical ones couched in theoretically relevant language (Bates et al., 1998). This was followed by comparing the insights emerging from our inductive investigation to those prevalent in the literature as a means of extending current theory. We elaborate on these insights in the analytic narrative that follows.

5. A brief history of free/open-source software[3]

In the early days of the computer industry (i.e., the 1950s and 1960s), hardware manufacturers sold their own operating systems as programs that were specific to particular computers and not portable to other computers; that is, each computer had its unique instruction set. However, many users of these computers concurrently wrote their own instructions to manage operations. These users freely exchanged these programs with one another, with community groups facilitating such sharing: users of IBM computers had the SHARE group while Univac users had USE. Parallel to such activity, a hacker culture spawned at MIT when it acquired the first PDP-1 around 1961 (Levy, 1984). The first artifacts of hackerdom – slang lists – as well as self-conscious discussions of the hacker ethic, started to propagate on the ARPANET in the early 1970s. Finally, Ken Thompson and Dennis Ritchie at Bell Labs developed Unix, whose initial diffusion within the computing community occurred because these individuals (and Bell Labs) were willing to share the source code for Unix, albeit without any support. Taken together, these activities point to the presence of a regime that revolved around the sharing of code among programmers that, in many ways, resembled the world of academia.

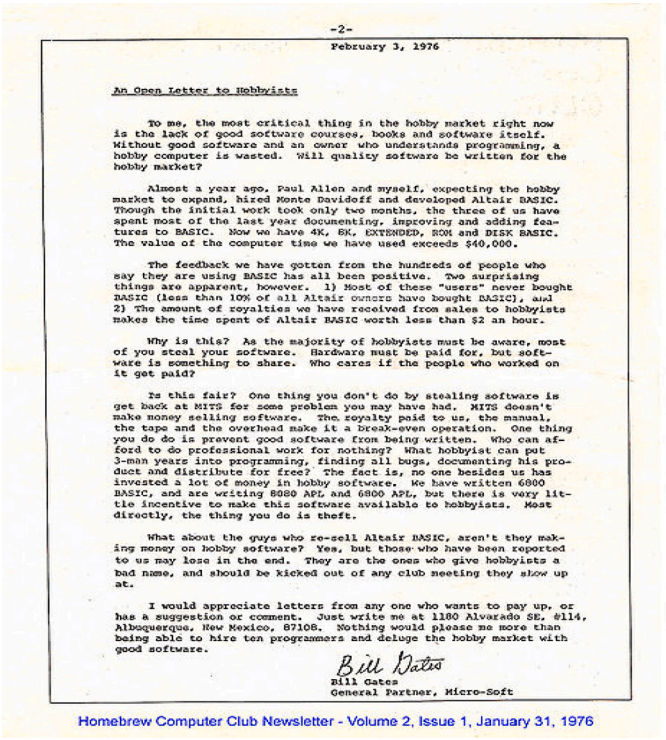
Improvements in microprocessor capacity in the 1970s spawned a rapid increase in the number of computer manufacturers that built small machines, like the Altair home computer kit, which was popular among hobbyists for playing games. A new generation of programmers that included Bill Gates and Paul Allen believed these devices would benefit from having pre-written, ready-to-use programming languages. Gates had written Basic for Altair and started to sell his program. Users thought that his program was expensive and also found that it had errors. They started to make modifications to it and shared these improvements. Soon, these adapted versions were better than the one Gates offered for sale. Responding to the situation, Gates wrote an open letter to the hobbyist community in 1976 (see Exhibit 1) suggesting that programmers who improved his software were in fact stealing his work and should stop doing so. More generally, while sharing of programs was common in the 1950s and 1960s, an alternative regime emerged during the 1970s that considered software programs to be like hardware – products based on proprietary knowledge and protected by IP (intellectual property) laws. In gaining protection for their work and preventing others from adapting or changing their code, software companies put themselves in a position to determine the directions in which computing developed.

Moreover, the widespread use of computers led to an increase in the number of novice users who lacked the skills to develop their own software, yet needed to use these programs at work. Such users preferred having access to "black-boxed" packages they could purchase. A proprietary regime incorporating these elements became ascendant within the software domain by the early 1980s (see Table 2 for a description of this regime).

As software firms retained proprietary control of their code, they determined the limits of what users could do with their new technologies. The increasing assertion of control by these firms led to rising apprehension among independent programmers who were part of an earlier era when software was freely developed, shared, and modified. To these programmers, software was not just a piece of engineering achievement, but a tool to express their creativity and imagination. Moreover, collaborative software development was not just a process of coming up with a great piece of technology, it was also a process of socialization among software developers. For these individuals, the growing power of the proprietary regime led to fears that strict

[3] This analytic narrative has drawn largely from the following books and articles: Armer (1980), Baldwin et al. (2003), Brooks Jr. (1995), Levy (1984), Moody (2001), Raymond (1999), Tozzi (2017), Weizer (1981), Williams and Stallman (2002), and Young (1994).

Exhibit 1
Gates' letter to the hobbyist community.



-2-

February 3, 1976

An Open Letter to Hobbyists

To me, the most critical thing in the hobby market right now is the lack of good software courses, books and software itself. Without good software and an owner who understands programming, a hobby computer is wasted. Will quality software be written for the hobby market?

Almost a year ago, Paul Allen and myself, expecting the hobby market to expand, hired Monte Davidoff and developed Altair BASIC. Though the initial work took only two months, the three of us have spent most of the last year documenting, improving and adding features to BASIC. Now we have 4K, 8K, EXTENDED, ROM and DISK BASIC. The value of the computer time we have used exceeds $40,000.

The feedback we have gotten from the hundreds of people who say they are using BASIC has all been positive. Two surprising things are apparent, however. 1) Most of these "users" never bought BASIC (less than 10% of all Altair owners have bought BASIC), and 2) The amount of royalties we have received from sales to hobbyists makes the time spent of Altair BASIC worth less than $2 an hour.

Why is this? As the majority of hobbyists must be aware, most of you steal your software. Hardware must be paid for, but software is something to share. Who cares if the people who worked on it get paid?

Is this fair? One thing you don't do by stealing software is get back at MITS for some problem you may have had. MITS doesn't make money selling software. The royalty paid to us, the manual, the tape and the overhead make it a break-even operation. One thing you do do is prevent good software from being written. Who can afford to do professional work for nothing? What hobbyist can put 3-man years into programming, finding all bugs, documenting his product and distribute for free? The fact is, no one besides us has invested a lot of money in hobby software. We have written 6000 BASIC, and are writing 8080 APL and 6800 APL, but there is very little incentive to make this software available to hobbyists. Most directly, the thing you do is theft.

What about the guys who re-sell Altair BASIC, aren't they making money on hobby software? Yes, but those who have been reported to us may lose in the end. They are the ones who give hobbyists a bad name, and should be kicked out of any club meeting they show up at.

I would appreciate letters from any one who wants to pay up, or has a suggestion or comment. Just write me at 1180 Alvarado SE, #114, Albuquerque, New Mexico, 87108. Nothing would please me more than being able to hire ten programmers and deluge the hobby market with good software.

Bill Gates
General Partner, Micro-Soft

Homebrew Computer Club Newsletter - Volume 2, Issue 1, January 31, 1976

copyright laws, motivated by profits, would stifle innovation and improvements in software. These frustrations reached a tipping point when AT&T, after accepting its consent decree (in the long-running anti-trust case that resulted in it being broken up) in 1982, started withdrawing free access to the Unix code that it had developed at Bell Labs. For hackers, who embraced the ethic of sharing software code with one another, this action was akin to the proverbial "last straw."

5.1. *Shaping the niche*

Richard Stallman, who worked at MIT's Artificial Intelligence Lab and was responsible for developing Emacs (Editing Macros), a text editor, was one such individual. He was dismayed by how the software sharing community, and the "hacker culture" associated with it, had begun to wither by the early 1980s. Indeed, many of the original programmers with whom he had worked were now being hired by firms producing proprietary software. Stallman strongly believed that software products should remain in the public domain where everyone could access, use and possibly improve them.

In an effort to recreate such a community, Stallman set out to develop a new operating system, written in the C programming language, that would be available to all. He believed that the operating system was the best place to focus his attention, because of its fundamental role in the management of a computer. He based his design on Unix, given that this (now proprietary) operating system had the flexibility to run on a variety of machines. Stallman named the system GNU, a recursive acronym for "GNU's not Unix". In 1984, he posted a call to others to join his project, and out of this effort, the free software movement was born.

5.1.1. *Framing an identity*

In addition to initiating the development of the new operating system, Stallman actively strove to create a collective action frame that provided a unique identity for the fledgling niche. Stallman chose the phrase "free" software to describe both GNU and this movement. In a manifesto he developed in 1985, Stallman invoked "four freedoms" designed to protect what he called the "natural rights" of users:

(a) the freedom to run a program for any purpose;
(b) the freedom to modify a program to suit one's needs;
(c) the freedom to redistribute copies either gratis or for a fee; and
(d) the freedom to distribute modified versions of programs so that all users could benefit from improvements.

Stallman's manifesto for software development directly contradicted the existing regime of proprietary ownership (see Table 2). Indeed, he posited that copyright limited the abilities of users to improve the software. He believed that "free" software would lead to greater innovation. Stallman's advocacy of these ideals, which bordered on evangelism, infused the movement with a distinct set of values that would guide its subsequent evolution.

5.1.2. *Crafting new institutional arrangements*

Stallman and his colleagues also crafted novel mechanisms that enabled the development of free software. On this front, there existed the fear that without some sort of protection, the source code developed would be appropriated by a for-profit entity. To prevent this from happening, Stallman drafted the General Public License (GPL). The GPL allowed source code to be modified by the user and distributed to others without restriction. However, the license also required that all modifications or derived works released to the public must be redistributed under the same terms. Stallman coined the phrase "copyleft" to characterize this counterintuitive legal standard. This form of license, and its

Table 2
Comparison of *proprietary* regime and *free/open-source* niche in the operating systems software sector.

	Proprietary regime	Free/Open-source niche
Knowledge base	Knowledge held by professional software developers employed by corporations. Each firm has its unique knowledge base not accessible to outsiders.	Knowledge is held by a distributed collective of professionals and amateurs who communicate using a wide variety of platforms/ online infrastructures.
Corporate governance structures	"Cathedral" form of organization: A strictly hierarchical system is used to split the plan into sub-tasks assigned to small teams of programmers. A cycle of planning, implementing, and testing is used to coordinate interdependencies and guarantee quality and compatibility. Development driven by corporate considerations.	"Bazaar" form of organization: A fluid community uses online forums to obtain suggestions/proposals for changes, that are then worked on by volunteers who propose solutions and improvements, with the most appropriate ones being selected by a smaller group of experts. Development is driven through meritocratic considerations.
Engineering and manufacturing practices	Software is developed according to a long-term product lifecycle strategy through a series of versions and updates. Each version cycle starts with obtaining requirement from key customers – large corporations – followed by implementation and testing. Large updates include involvement of providers of complementary software to guarantee compatibility.	Software is developed using a high-speed, iterative process whereby volunteers submit improvements and the best solutions are selected and implemented. The improvements are guided by the input from the user community: the programmers, consumers, and non-profits. The process tends to involve duplication and non-linear development.
Product characteristics	- Design: products designed to meet the needs of novice users; the "user-friendly" software is "black-boxed", i.e., cannot be modified by users - Compatibility: design integration ensures that products work with complementary products	- Design: products are not "user-friendly" in terms of the GUI used; however, they can be tinkered with because source code is available. - Security: ability to review the source code results in more secure software.
Market dynamics	Software is proprietary, and monetized/sold as a product to users. Products are differentiated to meet the different needs of users – primarily large corporations, but also smaller market segments like SME or education. Robust after-sales support provided. Competition based on the price-quality ratio.	Software is "free"/open, i.e., users can access the source code and adapt it to their own needs. Products distributed via the Internet with no "packaging" involved. No organized after-sales support provided (start-ups have emerged to provide this). Competition based on popularity.
Legal structure	Intellectual property laws — in particular, copyright and patent law — key for rent appropriation. This drives the firm-oriented software development process. Licensing provides very restricted rights to users	GNU GPL (and other similar licenses) ensures that knowledge base is in the public domain and restricts appropriation by anyone. This drives the community-oriented process software development process.
Ecosystem organization	- Support: extensive network of support – online, certified experts, etc. – ensures users can get help. - Private enforcement: organizations set up systems to crack down on piracy, like the BSA. - Hardware companies: collaboration with hardware developers to co-develop improvements. - Standards organization: to make proprietary formats industry standards.	- OSS start-ups: firms adapting open-source software to the need of corporate users essential for adoption. - Community groups: project-specific groups to develop and provide support. - Non-profits: such as FSF and OSI that promote software to wider society and steer internal dynamics. - Incumbents who provide resources/legitimacy to the movement
Landscape selection criteria	- Price-quality ratio - User-friendliness - Compatibility with other software applications	- Adaptability - Number of users (for network effects)

associated framing, was testimony to the movement's creativity and ingenuity in crafting institutional arrangements that enabled collaborative, sharing practices among its members.

Besides legal protection, the movement's leaders also foresaw the need for an organizational structure that supported the development of GNU, via sharing of information and the availability of technological resources. To facilitate this, they founded the Free Software Foundation (FSF) in 1985, whose prime purpose was the provision of knowhow, continued development of software, and advocacy for the free software movement. The persistent pursuit of this vision soon began to attract a steady slew of resources in terms of financing, equipment, and the involvement of a small yet highly skilled and dedicated band of hacker volunteers, who, during the 1984–1990 period, made substantial progress in building a large suite of non-proprietary, Unix-compatible tools. This community was motivated by non-pecuniary interests in providing their time and skills to develop new applications. Their efforts were indirectly supported by the academic community, which had access to the technological infrastructure for sharing these new tools. However, as of 1990, no one within this community had managed to develop a crucial element of the operating system – the kernel.[4] While the movement had launched an initiative, called Project Hurd, to address this shortcoming, this effort was plagued by delays and deferrals and, as a consequence, the movement began to stall.

The above description highlights some of the key dynamics related to the formation of a niche. Our account reveals the significant role played by actors who, through their ingenuity and sheer force of will, craft novel arrangements inspired by an underlying ethos to support their fledgling movement. Indeed, it is their imagination that enables the creation of a profoundly different "alternate universe" (also referred to as "socio-technical imaginaries" by Jasanoff and Kim (2015) and "imagined futures" by Beckert (2016)), one that provides an organizing concept that binds as well as propels the movement. Relatedly, these players imbue the niche with a distinct identity, one that enables it to establish points of contrast with the dominant regime, and serves to attract like-minded individuals to join the nascent community. In translating their ideas and ideals into a tangible set of arrangements, these actors engage in acts of "mindful deviation" (Garud and Karnøe, 2001) that serve as the basis of (potentially) new realities.

Our narrative also reveals how a niche, due to its radical, marginal, and quixotic nature, often remains on the margins and is "naturally protected" from scrutiny by actors within the regime. Such niches are subject to the vagaries of volunteer-based activity, given the minimal formal support they operate on, these limiting growth and impact of a movement (Smith et al., 2016). For a niche to regain vigor under these

[4] The kernel is the core of an operating system that connects and coordinates hardware with other parts of the system.

conditions requires a fresh infusion of resources and ideas. Fortunately, in this instance, this was just around the corner.

5.2. Amplifying the niche

In 1991, Linus Torvalds, a second-year computer science student at the University of Helsinki, initiated a hobby project on his newly acquired Intel 386 machine to improve upon the technical deficiencies of the Minix operating system.[5] Early in this effort, Torvalds was primarily interested in validating his programming skills. But as he added features to this program, it soon became apparent that this project was on its way to becoming an operating system. By that summer, Torvalds was working on the kernel for this system, as part of his larger vision of creating "a better Minix than Minix". In August 1991, he announced his kernel project to the world in a post on the Minix Usenet group (see Exhibit 2) and requested help in its further development. He released the first version of the new operating system (Version 0.01) in September 1991, with Ari Lemke, the system administrator at the university, naming the directory Linux.

5.2.1. Coalescing two niches

As it turned out, the kernel that Torvalds developed was compatible with components of the GNU project. This serendipitous occurrence enabled the fledgling Linux faction to build upon and benefit from the progress that the GNU collective had already made. At a broader level, it enabled the confluence between these two niches (Linux and GNU), providing the amalgamated movement with a huge boost in momentum that accelerated the technical activities that these disparate groups were engaged in. This convergence also extended to the organizational practices that Linux adopted. From its inception, Torvalds was insistent on developing an operating system that was totally free of cost.[6] By early 1992, as the fledgling operating system grew, Torvalds decided to release new versions of Linux (beginning with Version 0.12) using the GPL license. This further aligned this initiative with the GNU project in that it now explicitly acknowledged hacker values.

5.2.2. Crafting a novel participatory architecture to gain momentum

With this convergence in place, the next phase of Linux's evolution was simply remarkable. Beginning with Torvalds' announcement on the Minix List Serve, the embryonic operating system was worked on by a growing number of volunteers working on their personal computers and coordinating their activities through the now global Internet. Quality was maintained by the simple strategy of releasing new versions every week and getting feedback from hundreds of users within days. In this manner, this decentralized and loosely organized initiative was able to rapidly harness the minds and energies of a growing, like-minded community of programmers who were able to collectively craft components of this operating system. Moreover, such resource mobilization had a positive feedback loop: novel technological developments attracted new members to the community who in turn, generated innovation in an ongoing, continual manner (Garud et al., 2008). This dynamic set the stage for the movement to achieve the momentum required to make the niche self-sustaining. Linux 1.0 was released in early 1994, and as word about this new operating system spread across the Internet, thousands of free copies were downloaded. At this stage, Linux had about 50,000 users. By 2001, thousands of programmers – including four hundred regular contributors – had a hand in revising the code for the Linux kernel (Tozzi, 2017). Many of these individuals had originally been trained on Unix, and worked closely with one another to develop and institutionalize rules to manage, coordinate and improve the new operating system.

This mode of resource mobilization for software development was a drastic departure from conventional approaches. Until the development of Linux, everyone believed that software as complex as an operating system had to be developed in a carefully coordinated way by a relatively small, tightly-knit group of people. This thinking had been enshrined in Brook's Law, which indicated that having more programmers only made software more complex and unwieldy. Stallman himself believed in this approach, and as a result, the development of GNU remained centrally coordinated and controlled. Besides, while Stallman's expertise limited the number of volunteers who could collaborate with him, Torvalds's status as a student hacker made the Linux project more accessible to a larger group of programmers. Finally, while Stallman and the other free software proponents came from a world of advanced computers at universities like MIT, Torvalds had access to only a PC, which was more representative of the larger populace of computer enthusiasts who could potentially contribute to volunteer projects. These fundamental differences between the two initiatives played a significant role in their subsequent evolution.

5.2.3. Theorizing a new methodology

Other individuals within the community soon began to theorize about the unique and novel mode of software development that the Linux volunteers had pioneered. Eric Raymond became a passionate advocate for this new approach and, in a series of articles (that eventually became a book), contrasted what he termed the "bazaar" form of development (as exemplified by Linux) with the "cathedral" style, that had been adopted by proprietary software developers (as well as the FSF). As Raymond noted "Linus Torvalds's style of development—release early and often, delegate everything you can, be open to the point of promiscuity — came as a surprise. No quiet, reverent cathedral-building here — rather, the Linux community seemed to resemble a great babbling bazaar of differing agendas and approaches" (Raymond, 1999, p. 21). In sketching the distinctive features of Linux's development methodology, Raymond helped clarify a different pathway to software development. More significantly, this theorizing enabled the Linux movement to carve out a unique and resonant identity for itself.

In the midst of such theorizing, philosophical differences between the GNU and Linux initiatives now began to surface. On this front, while Stallman emphasized a moral framing and a more purist ideology with the primary focus being on the freedoms available to coders, the supporters of Linux opted for a more pragmatic approach that focused on emphasizing the functional and utilitarian aspects of the operating system. These differences soon morphed into acrimony between these two factions, one that would have significant ramifications for the trajectory of the niche.

These dynamics highlight how independent niches can sometimes coalesce and in doing so provide a momentum boost to the movement. Equally important is the reimagination and incorporation of a novel participatory architecture (Massa and O'Mahony, 2021) – powered by the availability of new infrastructural technologies – that enable fundamentally new forms of development. Taken together, these two forces enable the niche to gain the momentum required to become self-sustaining. However, our account also highlights the flip side of coalescing – i.e., rifts can emerge between the different factions that need to be addressed. Indeed, these concerns become particularly salient as the niche grows and begins to attract the attention of regime actors. This leads to a new wave of interactions, ones that we chronicle below.

5.3. Mainstreaming the niche

Even as the team of volunteers associated with Linux continued to build out the operating system, it now began to attract the attention of

[5] Minix had been developed by computer science professor Andrew Tannenbaum as a cheaper alternative (with limited features) to the full version of Unix, and was intended for use as a training tool. Minix gained popularity as it worked on PCs, unlike Unix which only worked on more expensive hardware.

[6] Indeed, one of his chief complaints about Tannenbaum's Minix system was its price tag. Torvalds released the first versions of Linux under a homegrown license that prevented anyone from using the code to make any money off it.

Exhibit 2
Torvalds' announcement of an open-source kernel.

From: torvalds@klaava.Helsinki.FI (Linus Benedict Torvalds)
Newsgroups: comp.os.minix
Subject: What would you like to see most in minix?
Summary: small poll for my new operating system
Message-ID: <1991Aug25.205708.9541@klaava.Helsinki.FI>
Date: 25 Aug 91 20:57:08 GMT
Organization: University of Helsinki
Hello everybody out there using minix -
I'm doing a (free) operating system (just a hobby, won't be big and professional like gnu) for 386(486) AT clones. This has been brewing since april, and is starting to get ready. I'd like any feedback on things people like/dislike in minix, as my OS resembles it somewhat (same physical layout of the file-system (due to practical reasons) among other things).
I've currently ported bash(1.08) and gcc(1.40), and things seem to work. This implies that I'll get something practical within a few months, and I'd like to know what features most people would want. Any suggestions are welcome, but I won't promise I'll implement them:-)
Linus (torvalds@kruuna.helsinki.fi)
PS. Yes - it's free of any minix code, and it has a multi-threaded fs. It is NOT portable (uses 386 task switching etc), and it probably never will support anything other than AT-harddisks, as that's all I have:-(.
(source: https://www.cs.cmu.edu/~awb/linux.history.html)

several start-ups who saw opportunities in taking it commercial. This resulted in the launch of a large number of distributions, so-called 'distros' – all based upon and revolving around the same Linux kernel but with different additions to the basic system – and related innovations in business models that typically involved the provision of service support given that the core product offering was "free". These versions reflected a growing interest among actors in commercializing this novel alternative and fueled further momentum for the niche.

5.3.1. *Heterogenous response from regime actors*

Moreover, there was increased recognition, among players within the extant proprietary regime, of the existence of this operating system. The reactions of these actors, interestingly enough, were quite varied. One group highlighted the risks that the new system posed, and took active steps to discredit it. The response of the most prominent player within the proprietary regime – Microsoft – reflected this. A series of leaked memos that came to be known as the "Halloween documents" revealed internal discussions within the software behemoth, in which it assessed Linux's strengths as well as the threat posed by this operating system. As the executive summary of the first Halloween document articulated:

> "Consequently, OSS [open-source software] poses a direct, short-term revenue and platform threat to Microsoft – particularly in server space. Additionally, the intrinsic parallelism and free idea exchange in OSS has benefits that are not replicable with our current licensing model and therefore present a long-term developer mind-share threat."

However, for another group of regime actors, this new operating system represented an intriguing opportunity, especially in their pursuit of competing more effectively with the dominant players, such as Microsoft. These actors – which included Netscape, IBM, and Oracle – soon began to explore ways in which they could forge a productive partnership with the growing niche, or at least borrow ideas and inspiration from their *modus operandi*. These dynamics highlight the heterogeneous nature of the response of regime actors to a niche, one that can range from hostility to accommodation, with many different variations in between.

For actors within the niche, their ongoing internal momentum as well as the increased scrutiny by regime players implied that they now had to think about taking their movement mainstream. Increasingly, professional computer users within large organizations (in particular, universities and the public sector) were considering adopting Linux for their servers, as they found this to be a better alternative compared to expensive proprietary systems, and saw in it the potential to adapt the code to address their unique needs. However, these actors also harbored significant concerns regarding the decentralized nature of Linux's development and the service support that would be accorded if they deployed this operating system. Moreover, the "free" nature of this software and the emphasis on sharing any updates with the community were antithetical to the manner in which conventional software businesses operated, given the ubiquity of intellectual property within the proprietary regime.

Given these realities, members within the movement now began to make the business case for Linux – i.e., they indicated that the operating system was now ready for use in commercial and industrial settings. This

involved emphasizing the technical merits of the software – i.e., its high reliability, low costs, and better features – as well as showcasing the superiority of the "bazaar" development process. Moreover, it required distancing Linux from some of the ethical connotations associated with GNU and the FSF faction, as well as crafting institutional arrangements that reflected this new position.

5.3.2. *Reframing identity*

In April 1998, a group comprising many of the long-standing members of the free software community (including the founding figures of well-known software suites and programming languages such as Linux, sendmail, Perl, Python, and Apache), as well as representatives from the industry associations IETF (Internet Engineering Task Force) and the Internet Software Consortium met to discuss issues related to the public perception of Linux.[7] For the attendees, the philosophically and politically laden term "free software" represented a key obstacle as it signaled hostility towards intellectual property rights and was unlikely to endear Linux to large vendors or IT administrators. While this position enabled the movement to juxtapose itself against the proprietary regime back in the 1980s, its utility going forward seemed limited.

After brainstorming and voting for a new option, the group converged on the term "open source", which had been suggested by Christine Peterson. In eschewing a moral position and emphasizing practicality, this terminology tapped into the faction's preference to focus on the delivery of a superior user experience, quality, and efficiency. They also promoted a document called "Open Source Definition" that defined an open-source software license and differentiated open-source from free software. Finally, they launched an organization called the Open Source Initiative (OSI) to provide institutional backing for their efforts.

In adopting an ideologically flexible approach, these actors sought to make a clean break from the free software faction. As can be expected, Stallman and his band of volunteers derided the open-source campaign, indicating that GNU's high-minded vision related to user freedom was being compromised by an emphasis on utilitarian ends. Raymond and other members of the open-source camp responded by indicating that the Free Software Foundation's message did not resonate with people who were not hackers, especially the business community. These dynamics highlight how festering differences between actors belonging to a niche can sometimes boil over. By this time, however, the GNU camp's influence over the larger movement had begun to wane and it was the open-source faction that became the public face and the driving force for the movement going forward.

These efforts to take the niche mainstream soon gained traction as various companies and organizations belonging to the proprietary regime began to view open-source software as a viable development model, and started to allocate significant resources to develop business models that would facilitate its commercialization. Most prominent among them was IBM who, in January 2000, made its endorsement of Linux public, and followed this up with an investment of $1 billion to support the development of the kernel. This investment in Linux provided a sheen of credibility to the open-source ecosystem that by now included a host of established players and start-ups (most notably Red Hat) besides the original band of volunteers. These actors enabled the rapid deployment and development of the Linux kernel into different computing environments. They also helped fund the OSDL (Open Source Development Labs), which subsequently became the Linux Foundation, a non-profit organization that was tasked to promote, protect and standardize the deployment of Linux in enterprise computing. Torvalds joined this organization in 2004 as the first OSDL fellow and is still affiliated with it.

These dynamics highlight how niche actors engage in the mainstreaming of a movement, one in which "extreme" positions are forsaken while more palatable elements are brought to the foreground. In doing so, they make their offering more comprehensible and appealing to conventional consumers, who are typically wary or simply unaware of how it works. Such cognitive mainstreaming also makes them more attractive to vendors who are looking at ways to improve their extant competitive position. To the extent that prominent incumbents lend their support, the niche is able to amass considerable resources as well as legitimacy. On their part, regime-based supporters need to perform a delicate balancing act, one in which their support for the movement does not stifle it. However, to the extent that the movement starts to gain traction and the knowledge base associated with it grows, it attracts resources from both new entrants and a larger set of regime actors on an ongoing basis.

5.3.3. *Coexistence of the niche and the regime*

More generally, the efforts at mainstreaming Linux, and the open-source principles underlying it, had the desired effect as the operating system has continued its rapid pace of growth in the 21st century, across different computing environments, both extant (such as servers) and emergent (this includes mobile devices and embedded systems). Interestingly enough, corporations are now the top contributors to the development of Linux.[8] These developments speak to the coexistence of an established niche alongside the entrenched proprietary regime (see also Nair and Ahlstrom, 2003). Put differently, two vastly different orders – each with their own mindsets and practices – now reside with one another as part of a hybrid regime that is characterized by institutional complexity (Greenwood et al., 2011). Over time, this has led to a proliferation of initiatives sponsored by actors that combine a methodology inspired by open-source principles while retaining key elements (such as protection of IP) of the extant order (Garud et al., 2002; West, 2003). These include such initiatives as the Android mobile operating system and the Ubuntu distribution (Tozzi, 2017). Besides, there has been a significant growth in the server market based on free/open-source software (see Fig. 1), with start-ups in this space relying on proprietary business practices in order to generate revenues. On the flip side, proprietary regime firms have adopted such practices as free and frequent updates to their software, as well as the engaging of users and developers in making continuous improvements. Moreover, as software has been reimagined as a service (as opposed to its original conceptualization as a product), companies have reconfigured their business models to significantly rely on open-source software for their underlying operations while generating revenue via the proprietary algorithms deployed in the provision of their services (Amazon Web Services being a notable example). This has also led to important components of our (open-source) digital infrastructure now being dependent on the involvement of corporates (Lifshitz-Assaf and Nagle, 2021). These dynamics are a testament to the intricate and somewhat precarious coexistence of hybrid orders.

5.3.4. *Influence of niche beyond focal regime*

Beyond the impact that the free/open-source software niche has had on the proprietary regime associated with the software, is the significant influence it has had on regimes associated with many different technologies. These include hardware (the Open Source Hardware Association (OSHWA) and the open-source development group at CERN being two prominent efforts in this space), industrial automation (via the Open Process Automation Forum, OPAF), and even clean energy (the Linux Foundation's SEAPATH initiative), among many others. In emphasizing the cultural values of openness, collaborative knowledge sharing,

[7] Richard Stallman was a notable non-invitee to this meeting, as he was deemed "inflexible and unwilling to engage in dialogue" (Williams, 2002, p. 163).

[8] IBM was among the top 20 contributors to the Linux kernel in 2020 (see Figure 2). Microsoft was the fifth largestcode contributor to Linux in 2011 (see also Table 1).

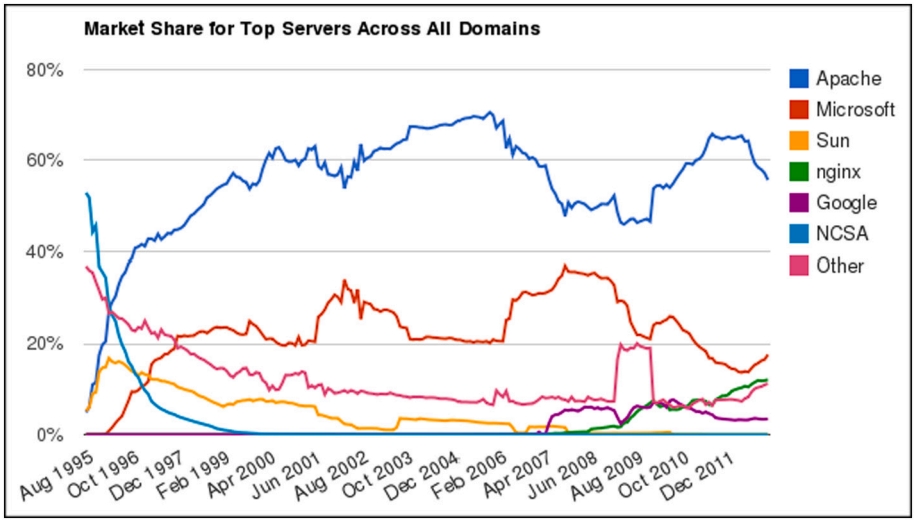


Fig. 1. Market share of Linux-based Apache for web server computers
Source: Netcraft (2012).

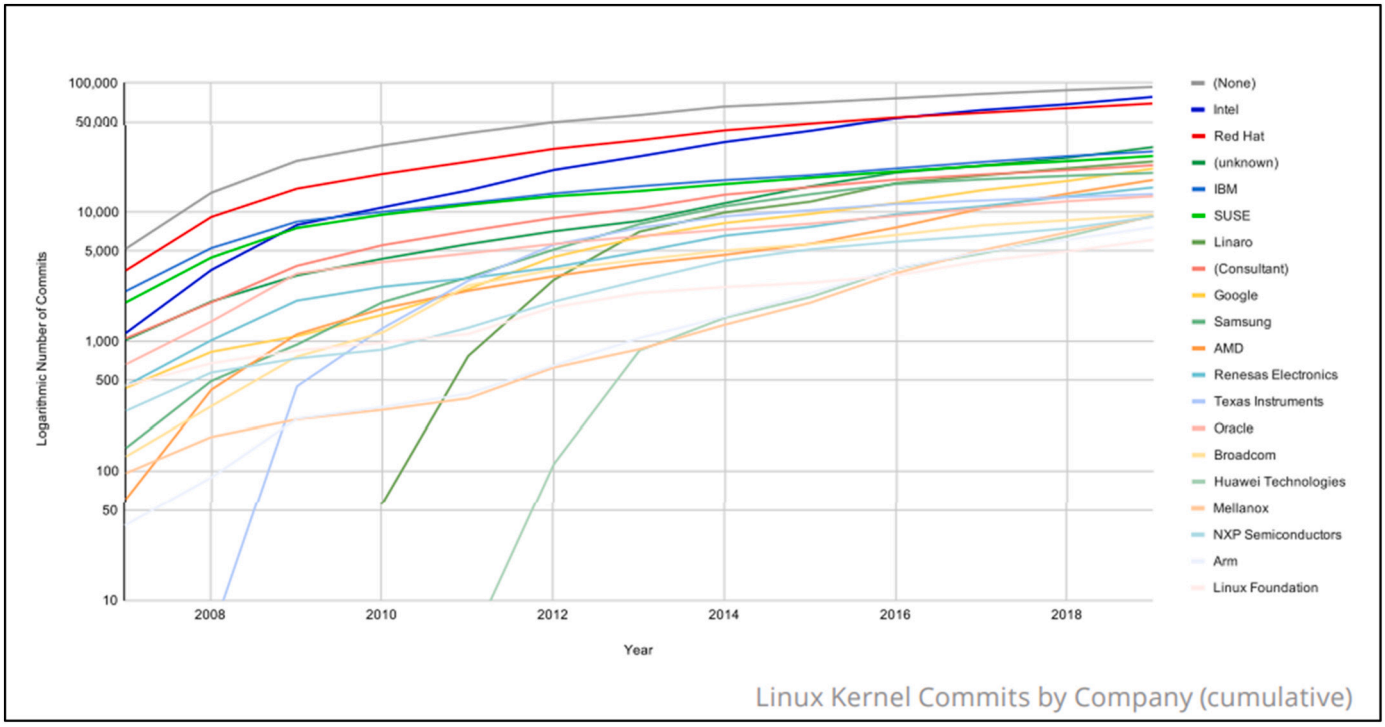


Fig. 2. Linux kernel commits by firm
Source: Linux Foundation (2020, p. 14).

mutual aid, respect, and conviviality, as well as offering a novel developmental methodology (enabled by new forms of materiality) that embodies these characteristics, the free/open-source software movement has afforded a powerful mindset and toolkit that has now become an integral part of the landscape. In doing so, it has inspired such initiatives as Wikipedia and the Creative Commons besides spurring the development of such practices as open data (Perkmann and Schildt, 2015), crowdsourcing (Afuah and Tucci, 2012), open innovation (Chesbrough, 2003), and the articulation of approaches that have been referred to as collective intelligence (Mulgan, 2018) and superminds (Malone, 2018). This points to the far-ranging effect that the ideas and practices exemplified in a niche can have – one that enables experimentation with new forms of organizing across multiple domains.

6. Discussion

In chronicling the development of the free/open-source software movement, we bring to life the role played by different actors as well as the cognitions and actions underpinning niche formation, development, and its interaction with the extant regime. Our theoretical lens, informed by the social movements and institutional entrepreneurship literatures, allows us to develop an inside-out narrative (and perspective) that captures the dilemmas and tensions that actors face in bringing their change to fruition. This, in turn, aids us in contributing to the extant literature on niche dynamics within the SNM and MLP literature. Specifically, we specify *shaping*, *amplifying*, and *mainstreaming* as three key processes that actors engage in to make their niche an enduring reality.

Moreover, in detailing the coexistence between the niche and regime, highlighting the heterogenous response of regime actors, and recognizing the span of influence of a niche, we provide new insights regarding the nature of technological transition (see Table 3).

6.1. Shaping

Our narrative suggests that actors are actively involved in shaping the contours of a technological niche. This includes imbuing it with a distinct identity, i.e., a set of core values, beliefs, and meanings that typically have been marginalized by the regime. Forging this identity provides the niche with its raison d'etre, and helps channel and propel the subsequent activities of actors associated with the nascent movement. Besides, this identity – and the framing that accompanies it – serves to familiarize potential participants and supporters with the niche's value proposition, in psychological, social, and economic terms. Ideology and conviction – as opposed to technological advancement or market need – can be drivers of niche formation. Our account also reveals the role that individuals play in articulating a niche's identity, imprinting it with a unique persona and set of ideals that can have a significant influence across domains and time.

We also highlight acts of institutional entrepreneurship that members belonging to the niche engage in to realize their imagined futures (Beckert, 2016; Garud et al., 2002; Jasanoff and Kim, 2015). This involves conceiving and crafting institutional devices and practices that are radically different from those embodied in the regime. Imagination and audacity, then, play a key role in enabling these communities to bring their "alternate universe" to fruition. These innovative arrangements are often coupled with creative framing strategies that serve to attract and bind others to the emergent niche. Early on, much of this activity appears quixotic and is confined to growing the niche internally, i.e., enrolling others who are sympathetic to the movement. Indeed, given their initial minuscule presence and their radically different ideology, these niches often remain "underground" and are "naturally" protected from the regime.

Our description also reveals the idiosyncrasies associated with a nascent niche. This suggests that movements can potentially lose momentum given their (initial) reliance on a small group of supporters for their sustenance and/or the inability to achieve the goals that they had set. A niche is sometimes unable to overcome these limitations and make the leap into the mainstream. In such cases, it requires a fresh transfusion of actors and ideas or risks becoming irrelevant and withering away.

6.2. Amplifying

Key to a niche gaining a more permanent footing is the ability of actors to augment its presence. We refer to this process as "amplifying", and define it as a set of activities that facilitate and propel the growth of the niche. One such mechanism that we observe involves coalescing, wherein a new niche links up to and builds upon the developments of an existing one and in doing so, expands the (collective) space and bolsters the momentum of the movement. While in this particular scenario this occurred somewhat serendipitously, there are likely situations in which actors associated with related (but distinct) niches strategically join forces as a means to increasing the combined entity's impact.

Additionally, our account demonstrates how actors sometimes craft an entirely new set of methods, practices, and organizational forms related to developing the technology that further accelerates niche growth. Here, the novel methodology took advantage of the affordances offered by the new medium, highlighting the key role that materiality can play in impacting niche dynamics. Given their novelty, such methodologies are often accompanied by theorizing that contrasts the new "way of doing things" within the niche from that in the extant regime. Taken together, these developments can contribute to the movement attracting significant participation and achieving the momentum

Table 3
Overview of activities associated with the free/open-source software movement.

	Cultural framing	Political opportunity structures	Resource mobilization	Institutional innovation
	The production of meaning driving the social movement	The vehicles through which actors engage in collective action	The garnering of tangible and intangible resources	The construction of an institutional architecture and initiatives aimed at gaining legitimacy
Niche shaping	- Hackers challenge the exclusivity of proprietary software - Stallman defines the 'four freedoms' as a bill of user rights - Provision of a clear definition of "free" - Stallman names new OS, GNU, to distinguish from Unix - Leaders articulate advantages of sharing code	- FSF founded to promote free software and coordinate software development	- Hacker community serve as volunteers - The movement locates allies within the academic community to access IT infrastructure	- "Copyleft" developed by Stallman as an alternate license to ensure sharing of code
Niche amplifying	- Eric Raymond serves as evangelist for Linux, theorizing the "bazaar" methodology - Rifts emerge within the movement, with leaders espousing views ranging from purist to pragmatic	- Members employ online forms of communication/ coordination (such as use of listservs) - Digital (platform) infrastructure enables rapid growth - Development on PC's lowers barriers of participation	- Torvalds coalesces Linux and GNU initiatives to gain momentum - Emergence of a large group of global volunteers that participate in OS development - "Incomplete by design" serves to foster participation	- Emergence of a set of rules to coordinate development of Linux ("bazaar" rules) - Users as producers - Legitimacy through the momentum of its development (and without formal products, brands or firms behind it)
Niche mainstreaming	- Pragmatists deliberately move away from the "free" and its anti-capitalist connotations - These individuals make a business case for Linux, emphasizing its reliability, security and transparency - Develop the label "open" and contrast this from "free"	- Open Source Summit serves to relabel Linux as "open" - OSI manifesto and OSDL/LF as forums for future development of Linux - Partnerships formed with some regime players	- Entry of start-ups intent on commercializing Linux - IBM and other incumbents provide significant political and financial support	- Development of business models that provide support services to open software products - Open source definition document sets parameters for future development - Legitimacy gains via regime actor endorsement

required to become a self-sustaining niche with a unique identity.

Even as it establishes itself, the movement begins to face pressures, both from external and internal forces. On this front, it attracts attention from players belonging to the regime, some of whom take active steps to delegitimize it as a means to defending their own interests. Moreover, as it incorporates more participants, fissures often emerge among niche actors in terms of charting the future identity and trajectory of the movement. Specifically, rifts develop between the purists, who take an ideological and revolutionary view of the movement, and the pragmatists, who are more willing to work with the regime and emphasize a "change from within the system" approach. This constellation of forces can impact the momentum of a niche, necessitating a round of resolutions as the movement plows forward.

6.3. Mainstreaming

As the movement gains momentum, the stage is set for more significant interaction between the niche and the extant regime. While much prior work has emphasized the resistance that these actors display, we find significant heterogeneity in their responses – i.e., a subset of incumbents looks to the niche as a source for new ideas that could potentially invigorate their own operations and help them compete more effectively with others in the regime. By endorsing and supporting the niche, these actors provide it with much-needed legitimacy. In addition, there are others who either passively follow ("wait and see") or continue to ignore niche developments. Moreover, regime actors can themselves be classified into producers and users of the technology, with the latter having their own motivations for (and concerns with) engaging with the niche. This heterogeneity points to the multiplicity of pathways through which niche actors can plot their entry into the regime.

Along these lines, our account demonstrates how these players take active steps to make themselves more acceptable to the regime - a process we term "mainstreaming". This involves framing that generates labels and meanings more suitable and comprehensible to the majority. It can sometimes require excising undesirable connotations associated with the niche. On a different front, there is the spawning of start-ups engaged in entrepreneurial and commercial activities related to the movement, that attempt to span the gap between the niche and the regime. And finally, there is partnering with regime actors – that include producers and users, among others – as well as the crafting of institutional arrangements that further entrench the niche. Taken together, these activities are representative of how niche actors navigate a political environment rife with possibilities and peril in order to gain traction for their movement.

Significantly, our narrative suggests that mainstreaming activity as well as the embrace of ideas and practices from the movement by incumbents can sometimes lead to the coexistence of the niche with the regime – i.e., these radically different "ways of doing things" exist side-by-side, with one not replacing or subsuming the other. Indeed, such "creative coexistence", is one in which the niche and regime forge a symbiotic relationship, and represents a viable alternative to "creative destruction", or substitution of the regime by the niche. This pattern of technology evolution has also been observed in such disparate domains as steel production and kidney disease treatment (Nair and Ahlstrom, 2003). Here we distinguish coexistence from reconfiguration (De Haan and Rotmans, 2011; Geels and Schot, 2007), and highlight the possibility that niche-regime interactions can result in the formation of a more complex terrain, one that supports multiple forms of organizing (Fuenfschilling and Truffer, 2014 also allude to such a possibility). This coexistence, in turn, enables actors to create hybrid modes that combine elements from the two canonical forms. This can lead to a scenario where even as the niche gains traction, its effects are somewhat diluted and even remain unacknowledged (i.e., they are taken for granted). These developments allude to the intricate outcomes that manifest when a niche interacts with a regime. Moreover, this state of affairs can exist for a considerable amount of time, creating the impression that transitions in practice are often "unfinished" or "incomplete" (Garud et al., 2008).

Finally, our case demonstrates how the ideas and practices associated with a niche can have a far-ranging impact, spanning many domains. What began as a quixotic endeavor that was a response to developments taking place in a specific regime has morphed into a higher-order movement that has provided an alternate organizational form and associated institutional innovations. This influence speaks to the abiding principles embodied in the niche that have strongly resonated with actors seeking to foster change in their own respective regimes. Theoretically, this suggests the need to trace niche influence in more expansive terms, i.e., beyond the focal regime and into the landscape.

Taken together, our exposition of these three processes – shaping, amplifying, and mainstreaming – spotlight the value of employing a generative lens grounded in the social movements and institutional entrepreneurship literature – to understand niche dynamics. In providing a detailed exposition of the cognitions and actions that unfold as a niche emerges and evolves, this perspective "brings to life" the construction of new paths from inception to institutionalization (see also Joerges, 1988). In doing so, it enables us to connect the micro-motives of actors (operating both individually and collectively) with the meso-order of regime transition and highlights the intricate nature of this process.

6.4. Theoretical contributions

A key contribution of our paper is to enrich conversations taking place within the SNM and MLP domains, and offer a useful complementary perspective to the extant literature. Along these lines, Geels (2010) observed:

> "The MLP originates from the Twente school's quasi-evolutionary theory (Rip, 1992, Schot, 1992, Rip and Kemp, 1998) that aimed to make evolutionary variation–selection–retention mechanisms more sociological via crossovers with interpretivism/constructivism (mainly from STS)."

Nevertheless, the SNM/MLP literature is still largely influenced by evolutionary economics theorizing, as evidenced by concepts like socio-technical regimes, technological trajectories, path dependence, routines, search and (behavioral) learning (from MLP) and protective spaces, demonstration projects, experimenting and empowering (from SNM) all drawing from the variation-selection-retention cycle that is central to this intellectual domain. This has contributed to a limited conceptualization of agency within the extant scholarship. Geels (2020, p. 2) acknowledges this limitation, indicating that the MLP was initially developed as a 'global' (or "outside-in") model to provide a big picture understanding of longitudinal socio-technical transition processes, with its 'local' (or "inside-out") model remaining underdeveloped. In this paper, we incorporate ideas and insights from the social movements and institutional entrepreneurship literature to provide the foundations for a

richer micro-level understanding of these transition processes, one that is grounded in actor cognitions and actions, as well as the tools that they employ. Our theoretical exposition makes actors and agency more central to the analysis and highlights the role of imagination, ingenuity, and political maneuvering in transition endeavors. In developing our "inside-out", prospective perspective, we demonstrate how embedded agency is enacted and draw attention to the contingent, capricious, and contested nature of niche development, one that often generates outcomes that are both unexpected and complex. Our contributions, then lie in further enabling the theoretical crossover between institutional sociology and evolutionary economics (by bringing the actors back in) to more fully realize the visions that the founders of the Twente school had articulated in their early work (Rip and Kemp, 1998; Schot, 1992).[9] We expound on our specific contributions to the various literature streams below (see also Table 4).

The SNM literature has emphasized shielding, nurturing, and empowerment as three key processes associated with niche development (Smith and Raven, 2012). The TIS (technological innovation systems) literature defines 'strategic collective system building' as efforts by networks of entrepreneurs to build a supportive environment and infrastructure for their novel technology, and provides a detailed set of categories that constitute such activity (Planko et al., 2016). To these, we add three mechanisms that represent "processes in practice" and reflect an "inside-out" micro-orientation — shaping, amplifying, and mainstreaming. *Shaping* refers to constructing the contours and related set of institutional arrangements for the niche and highlights the "identity work" actors need to engage in during niche formation. This contrasts with the SNM literature that largely describes niches as pre-existing entities and emphasizes shielding as a key activity. *Amplifying* often involves interactions between niches and is sometimes accompanied by the creation of entirely new participation architectures and practices, both of which are distinct from the networking, visioning and learning activities referenced in the SNM literature. Finally, *mainstreaming* refers to the meaning-making activity that actors engage in to make a niche comprehensible and acceptable to regime members (in particular, producers and consumers) and complements the fit and conforming/stretching and transforming processes that are the focus of the SNM stream of research. Specifically, mainstreaming involves *simultaneously* conforming and transforming and is akin to the idea of "robust design" (Hargadon and Douglas, 2001) – i.e., it enables actors to embed their innovations within the established regime while retaining the ability to modify it over time. More broadly, our study emphasizes the role of imagination and ingenuity, often exercised by individuals, in shaping the emergence and evolution of the niche. Examining "niches in the making", we suggest, can provide us with a more grounded understanding of how the more macro mechanisms identified in the SNM literature actually work in practice. Along these lines, developing a perspective that is premised on a "niche as a social movement" enables us to more seamlessly integrate a disparate set of macro-actions (such as shielding, visioning, networking, learning, empowering, etc.) identified in prior studies into a more coherent flow of activity, that collectively contributes to the (potential) construction of a new path.

Table 4
Comparison of processes specified in the SNM literature with our findings.

Strategic niche management (SNM)	Social movement theory/institutional entrepreneurship
Shielding:	**Shaping:**

- Protecting the niche from the technological regime
  - Passive shielding: Niche exists in a space where selection pressures are felt less keenly (based on geography, institutional or user type)
  - Active shielding: Niche created through deliberate actions (such as policy measures and incubator units)
	- Imbuing niche with a distinct identity, i.e., a set of core values, beliefs and meanings; such framing activity familiarizes participants with the niche's value proposition
	- Individuals imprint the niche with a unique ideology
	- Acts of institutional entrepreneurship: crafting alternative original institutional arrangements, devices and practices
	- Niche "naturally protected" from regime (incumbents unaware of/ignore niche due to their radically different nature) but is fragile

Nurturing:	**Amplifying:**

- "Experiments" within the niche to develop and improve alternative technologies
- Comprises three critical elements:
  - Expectations: articulating goals of ongoing projects
  - Learning: both first-order (accumulation of data) and second-order (alternate ways of supporting niche)
  - Networking: collaborating to generate resources and increase support
	- Activities/strategies that enable niche to gain momentum and amplify its presence
	- Coalescing: niche builds on developments made by other (prior or simultaneous) movements
	- Employ affordances provided by changes in underlying technology to craft new organization forms and associated methods/practices
	- Theorizing the new forms/practices/methods
	- Fissures can develop within growing niche that need to be managed

Empowering:	**Mainstreaming:**

- Two common approaches:
  - Fit-and-conform: improving technologies to perform better on mainstream selection criteria
  - Stretch-and-transform: changing the regime's selection environment
	- Taking active steps to make the niche more acceptable/palatable to regime actors
	- Reframing activity to connote different meanings and excise undesirable associations
	- Spawning of start-ups that bridge niche and regime
	- Partnerships with sympathetic regime actors
	- Simultaneously "conform and transform": leverage established regime while changing it

In indicating that a niche and an extant regime sometimes co-exist with one another, we contribute to the MLP literature. Geels and Schot (2007) identified four transition pathways: transformation, reconfiguration, technological substitution, and dealignment and realignment. The transition state we describe operates differently from these trajectories, and in particular, represents a departure from newcomer substitution or incumbent incorporation that has dominated the broader literature on technological change. This coexistence of different paradigms, incorporating different philosophies and practices, can spawn many hybrid forms of organizing and result in an institutional terrain that is complex in nature (Greenwood et al., 2011). These concepts — institutional complexity and regime hybridity — merit closer investigation in future transition studies. Moreover, the ongoing nature of change and the broader impact of the niche (across regimes and into the landscape) speaks to the elaborate temporal and spatial dynamics of transitions, that require further unpacking in subsequent work. Also, our observation regarding the different responses of regime actors towards the niche indicates their mixed motivations and contributes to the

[9] We would like to acknowledge that labels such as "outside-in" and "inside-out" should not be interpreted in their literal sense. While our study primarily adopts a constructivist perspective to understanding technology transitions, we do acknowledge the impact of broader macro processes on the emergence and evolution of a niche, as reflected by the term "embedded agency". Likewise, studies in SNM and MLP that have primarily emphasized an evolutionary perspective would benefit from more explicit recognition of the underlying micro-processes – cognitive, political and material – that actors engage in to facilitate transitions (Smith and Raven, 2012 represents an effort in this direction). Studies that span the "micro" and the "macro" to explore more complex configurations of agentic behavior represent an exciting and important direction for future research.

growing consensus that suggests incumbents vary in their role in transition processes (Berggren et al., 2015; Grin, 2020; Steen and Weaver, 2017; Turnheim and Sovacool, 2020). In contrast to these studies, however, we observe that incumbents are reactive (albeit in different ways) rather than proactive in their involvement with the transition. And finally, in examining the changes taking place in the operating system software sector (an integral aspect of our digital infrastructure), we extend the applicability of the MLP/SNM frameworks beyond the oft-studied sustainability transitions. In addition to expanding generalizability, our study enables us to identify new mechanisms and processes unfolding during transitions that can be "ported back" to the sustainability domain.

Our account also offers new insights into the literature on social movements and institutional entrepreneurship within innovation studies. In chronicling the role played by individuals in crafting the contours and associated institutional arrangements of the incipient movement, we highlight how actors leave a lasting imprint and legacy on a nascent movement. This emphasis contrasts with the focus on structural factors that have dominated the social movements literature and reconnects with scholarship within this stream that views leaders as political entrepreneurs who mobilize resources and create organizations in response to incentives, risks, and opportunities (McCarthy and Zald, 1977; Zald and Ash, 1966). Second, we highlight the crucial role that materiality can play in amplifying and spreading a movement, via the emergence of new information technologies (such as the Internet) that fundamentally reconfigure political opportunity structures and resource mobilization and create affordances that enable actors to organize and coordinate activity in novel ways (see also Marres, 2012). Studying the "tools of revolution", we believe, offers a useful complement to the social, political, and cognitive elements that have been examined as drivers of social movements (Davis and Sinha, 2021). Third, we specify the fissures that emerge within a movement, most notably between so-called purists and pragmatists, that require resolution and shape its future trajectory. This points to the multitude of ideas and motives that exist as actors pursue a common cause, these fostering tension, and contradiction, even as a movement gains momentum (McCarthy and Zald, 1977). Fourth, we reveal the ongoing and unfinished nature of social movements, one in which the new order, while becoming part of the regime, does not quite replace or be subsumed by it. Such outcomes reflect the complex interaction between the movement and the status quo that requires further scrutiny in future research. Finally, in tracing and specifying the circuitous transition path of a novel technology, we highlight the intricate interactions between actors and institutions – what Barley (2008) refers to as "coalface" institutionalism — and identify imagination in concert with the invention of material devices and organizational practices as key drivers of a process of path creation (Garud and Karnøe, 2001). Examining the role of actors as institutional entrepreneurs and integrating them into theories that take a more "structural" approach to change/transition represents an important direction to pursue in ensuing scholarship.

While the paper makes attempts to contribute to several literature, it is not without limitations. First, using a microhistories approach (Hargadon, 2015) allows us to analyze historical phenomena and past events by using archival data as if the events happened successively. Yet, while such an approach confines the risks of hindsight bias, some data may be incomplete or filtered over time as not all individuals, organizations, or events left equally detailed documentation. Second, we selected a research environment that was relatively unaffected by governmental policies or political pressures. The key elements in the processes of niche shaping, amplifying, and mainstreaming may look different in settings with a stronger role for government like renewable energy or infrastructure (e.g., Smith, 2007; Turnheim and Geels, 2019). Third, like much of earlier work on technological transitions (Geels, 2019), our analysis dealt with a relatively successful technological niche that was able to break through, and resulted in the sustained coexistence of disparate regimes. Future research could explore technological niches that fail to make it to the mainstream to understand the role that embedded agency and other factors play in engendering such outcomes.

From a policy perspective, our study highlights the need for examining, in greater depth, the socio-political and cognitive drivers — alongside the traditionally examined techno-economic factors — that contribute to technological change. Indeed, there is much to gain in adopting a prospective lens, founded on the social movements and institutional entrepreneurship literatures, to understand the many sustainability transitions unfolding around the world and involving various innovations (Köhler et al., 2019). Taking a deep dive into how actors individually and collectively craft new identities and institutional arrangements, employ creative framing and novel resource mobilizing strategies as well as skillfully maneuver politically fraught environments to gain a favorable position for their sustainable technologies represents a fallow area for future research. While our study has limitations given that it is based on a single case study, this offers up the intriguing possibility of conducting more research that would potentially broaden/deepen our understanding of the micro-agentic mechanisms at play here. In particular, exploring and characterizing the role of governments and public sector organizations as institutional entrepreneurs that shape the contours of an emerging technology trajectory is a particularly fruitful domain of inquiry (Mazzucato, 2016). Likewise, studies that observe the interaction that takes place, the relationship that ensues, and the terrain that develops between the emergent niche and the established regime over time can provide us with much-needed insights into the actual nature of the transition. Along these lines, policies that trigger premature "closure" of a trajectory, based on assumptions of dominance as the natural order, may be counter-productive. Taken together, these scholarly forays would provide us with a more comprehensive and generative understanding of the "processes in practice" that underlie sustainability transitions and the institutionally complex scenarios that result.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

CRediT authorship contribution statement

Sanjay Jain: Conceptualization, Investigation, Methodology, Writing – original draft, Writing – review & editing, Supervision. **Habib A. Islam:** Methodology, Investigation, Writing – original draft, Writing – review & editing. **Martin C. Goossen:** Writing – original draft, Writing – review & editing. **Anil Nair:** Conceptualization, Investigation, Writing – review & editing, Supervision.

Declaration of competing interest

No interests to declare.

Data availability

Data will be made available on request.

Acknowledgements

We are grateful for the guidance provided by the editor, Professor Anna Bergek, and the generous feedback and constructive comments of three anonymous reviewers that have significantly sharpened this manuscript. In addition, we would like to thank Roger Dunbar and Bhatt Vadlamani for their contributions to earlier versions of this study.

References

Afuah, A., Tucci, C.L., 2012. Crowdsourcing as a solution to distant search. Acad. Manag. Rev. 37, 355–375.

Ansari, S., Garud, R., Kumaraswamy, A., 2016. The disruptor's dilemma: TiVo and the US television ecosystem. Strateg. Manag. J. 37, 1829–1853.

Armer, P., 1980. Share - a eulogy to cooperative effort. Ann. Hist. Comput. 2, 122–129.

Baldwin, C.Y., O'Mahony, S., Quinn, J., 2003. IBM and Linux (A) (No. 903– 083), Harvard Business School Case. Harvard Business School, Cambridge (MA).

Barley, S.R., 2008. Coalface institutionalism. In: Greenwood, R., Oliver, C., Lawrence, T. B., Meyer, R.E. (Eds.), The SAGE Handbook of Organizational Institutionalism. SAGE Publications, London (UK), pp. 491–518.

Bates, R.H., Greif, A., Levi, M., Rosenthal, J.-L., Weingast, B.R., 1998. Analytic Narratives. Princeton University Press, Princeton (NJ).

Beckert, J., 2016. Imagined Futures: Fictional Expectations and Capitalist Dynamics. Harvard University Press, Cambridge (MA).

Benford, R.D., Snow, D.A., 2000. Framing processes and social movements: an overview and assessment. Annu. Rev. Sociol. 26, 611–639.

Berggren, C., Magnusson, T., Sushandoyo, D., 2015. Transition pathways revisited: established firms as multi-level actors in the heavy vehicle industry. Res. Policy 44, 1017–1028.

Bijker, W.E., 1997. Of Bicycles, Bakelites, and Bulbs: Toward a Theory of Sociotechnical Change. MIT Press, Cambridge (MA).

Bijker, W.E., Hughes, T.P., Pinch, T.J., 1987. The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology. MIT Press, Cambridge (MA).

Blumer, H., 1969. Symbolic Interactionism: Perspective and Method. Prentice Hall, Englewood Cliffs (NJ).

Brooks Jr., F.P., 1995. The Mythical Man-month: Essays on Software Engineering. Addision-Wesley Longman, Crawfordsville (IN).

Chesbrough, H.W., 2003. Open Innovation: The New Imperative for Creating and Profiting From Technology. Harvard Business School Press, Boston (MA).

Christensen, C.M., Bower, J.L., 1996. Customer power, strategic investment, and the failure of leading firms. Strateg. Manag. J. 17, 197–218.

Corbin, J., Strauss, A., 1990. Basics of Qualitative Research: Techniques and Procedures for Developing Grounded Theory. SAGE Publications, Thousand Oaks (CA).

Cornelissen, J.P., Werner, M.D., 2014. Putting framing in perspective: a review of framing and frame analysis across the management and organizational literature. Acad. Manag. Ann. 8, 181–235.

Davis, G.F., Sinha, A., 2021. Varieties of uberization: how technology and institutions change the organization (s) of late capitalism. Organ. Theory 2, 1–17.

De Haan, J.H., Rotmans, J., 2011. Patterns in transitions: understanding complex chains of change. Technol. Forecast. Soc. Chang. 78, 90–102.

DiMaggio, P., 1988. Interest and agency in institutional theory. In: Zucker, L.G. (Ed.), Institutional Patterns and Organizations Culture and Environment. Ballinger, Cambridge (MA), pp. 3–21.

Dosi, G., 1982. Technological paradigms and technological trajectories: a suggested interpretation of the determinants and directions of technical change. Res. Policy 11, 147–162.

Edwards, B., McCarthy, J.D., 2004. Strategy matters: the contingent value of social capital in the survival of local social movement organizations. Soc. Forces 83, 621–651.

Eisenhardt, K.M., 1989. Making fast strategic decisions in high-velocity environments. Acad. Manag. J. 32, 543–576.

Elzen, B., Geels, F.W., Leeuwis, C., Van Mierlo, B., 2011. Normative contestation in transitions 'in the making': animal welfare concerns and system innovation in pig husbandry. Res. Policy 40, 263–275.

Farla, J., Markard, J., Raven, R., Coenen, L., 2012. Sustainability transitions in the making: a closer look at actors, strategies and resources. Technol. Forecast. Soc. Chang. 79, 991–998.

Fligstein, N., 1997. Social skill and institutional theory. Am. Behav. Sci. 40, 397–405.

Fuenfschilling, L., Truffer, B., 2014. The structuration of socio-technical regimes—conceptual foundations from institutional theory. Res. Policy 43 (4), 772–791.

Garud, R., Karnøe, P., 2001. Path creation as a process of mindful deviation. In: Garud, R., Karnøe, P. (Eds.), Path Dependence and Creation. Lawrence Erlbaum Associates, Mahway (NJ), pp. 1–38.

Garud, R., Jain, S., Kumaraswamy, A., 2002. Institutional entrepreneurship in the sponsorship of common technological standards: the case of Sun Microsystems and Java. Acad. Manag. J. 45, 196–214.

Garud, R., Hardy, C., Maguire, S., 2007. Institutional entrepreneurship as embedded agency: an introduction to the special issue. Organ. Stud. 28, 957–969.

Garud, R., Jain, S., Tuertscher, P., 2008. Incomplete by design and designing for incompleteness. Organ. Stud. 29, 351–371.

Garud, R., Kumaraswamy, A., Karnøe, P., 2010. Path dependence or path creation? J. Manag. Stud. 47, 760–774.

Geels, F.W., 2002. Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study. Res. Policy 31, 1257–1274.

Geels, F.W., 2010. Ontologies, socio-technical transitions (to sustainability), and the multi-level perspective. Res. Policy 39, 495–510.

Geels, F.W., 2019. Socio-technical transitions to sustainability: a review of criticisms and elaborations of the multi-level perspective. Curr. Opin. Environ. Sustain. 39, 187–201.

Geels, F.W., 2020. Micro-foundations of the multi-level perspective on socio-technical transitions: developing a multi-dimensional model of agency through crossovers between social constructivism, evolutionary economics and neo-institutional theory. Technol. Forecast. Soc. Chang. 152, 119894.

Geels, F., Raven, R., 2006. Non-linearity and expectations in niche-development trajectories: ups and downs in dutch biogas development (1973–2003). Technol. Anal. Strateg. Manag. 18, 375–392. https://doi.org/10.1080/09537320600777143.

Geels, F.W., Schot, J., 2007. Typology of sociotechnical transition pathways. Res. Policy 36, 399–417.

Geertz, C., 1973. Thick description: toward an interpretive theory of culture. In: Geertz, C. (Ed.), The Interpretation of Cultures: Selected Essays. Basic Books, New York (NY), pp. 3–30.

Glaser, B.G., Strauss, A.L., 1967. The Discovery of Grounded Theory: Strategies for Qualitative Research. Aldine Publishing Company, Chicago (IL).

Goffman, E., 1974. Frame Analysis: An Essay on the Organization of Experience. Harvard University Press.

Grandy, G., Mills, A.J., Durepos, G., Wiebe, E., 2010. Encyclopedia of Case Study Research. SAGE Publications, Thousand Oaks (CA).

Greenwood, R., Raynard, M., Kodeih, F., Micelotta, E.R., Lounsbury, M., 2011. Institutional complexity and organizational responses. Acad. Manag. Ann. 5, 317–371.

Grin, J., 2020. "Doing" system innovations from within the heart of the regime. J. Environ. Policy Plan. 22, 682–694.

Hara, N., Rosenbaum, H., 2008. Revising the conceptualization of computerization movements. Inf. Soc. 24, 229–245.

Hargadon, A., 2015. From what happened to what happens: using microhistorical case studies to build grounded theory in organization studies. In: Elsbach, K.D., Kramer, R.W. (Eds.), Handbook of Qualitative Organizational Research. Routledge, New York (NY), pp. 122–133.

Hargadon, A.B., Douglas, Y., 2001. When innovations meet institutions: Edison and the design of the electric light. Adm. Sci. Q. 46, 476–501.

Hargrave, T.J., Van de Ven, A.H., 2006. A collective action model of institutional innovation. Acad. Manag. Rev. 31, 864–888.

Hargreaves, T., Hielscher, S., Seyfang, G., Smith, A., 2013. Grassroots innovations in community energy: the role of intermediaries in niche development. Glob. Environ. Chang. 23, 868–880.

Henderson, R.M., Clark, K.B., 1990. Architectural innovation: the reconfiguration of existing product technologies and the failure of established firms. Adm. Sci. Q. 35, 9–30.

Hess, D.J., 2005. Technology-and product-oriented movements: approximating social movement studies and science and technology studies. Sci. Technol. Hum. Values 30, 515–535.

Hess, D.J., 2018. Energy democracy and social movements: a multi-coalition perspective on the politics of sustainability transitions. Energy Res. Soc. Sci. 40, 177–189.

Hoogma, R., Kemp, R., Schot, J., Truffer, B., 2002. Experimenting for Sustainable Transport: The Approach of Strategic Niche Management. Spon Press, New York (NY).

Iacono, S., Kling, R., 2001. Computerization movement: the rise of the internet and distant forms of work. In: Yates, J.F., Van Maanen, J. (Eds.), Information Technology and Organizational Transformation: History, Rhetoric, and Practice. SAGE Publications, Newbury Park (CA), pp. 93–135.

Jain, S., 2012. Pragmatic agency in technology standards setting: the case of ethernet. Res. Policy 41, 1643–1654.

Jain, S., 2020. Fumbling to the future? Socio-technical regime change in the recorded music industry. Technol. Forecast. Soc. Chang. 158, 120168.

Jain, S., Ahlstrom, D., 2021. Technology legitimacy and the legitimacy of technology: the case of chronic kidney disease therapies. J. Eng. Technol. Manag. 62, 101653.

Jain, S., George, G., 2007. Technology transfer offices as institutional entrepreneurs: the case of Wisconsin Alumni Research Foundation and human embryonic stem cells. Ind. Corp. Chang. 16, 535–567.

Jain, S., Sharma, D., 2013. Institutional logic migration and industry evolution in emerging economies: the case of telephony in India. Strateg. Entrep. J. 7, 252–271.

Jasanoff, S., Kim, S.-H., 2015. Dreamscapes of Modernity: Sociotechnical Imaginaries and the Fabrication of Power. University of Chicago Press, Chicago (IL).

Jick, T.D., 1979. Mixing qualitative and quantitative methods: triangulation in action. Adm. Sci. Q. 24, 602–611.

Joerges, B., 1988. Technology in everyday life: conceptual queries. J. Theory Soc. Behav. 18, 219–237.

Jørgensen, U., 2012. Mapping and navigating transitions—the multi-level perspective compared with arenas of development. Res. Policy 41, 996–1010.

Kemp, R., Schot, J., Hoogma, R., 1998. Regime shifts to sustainability through processes of niche formation: the approach of strategic niche management. Technol. Anal. Strateg. Manag. 10, 175–195. https://doi.org/10.1080/09537329808524310.

Kling, R., Iacono, S., 1988. The mobilization of support for computerization: the role of computerization movements. Soc. Probl. 35, 226–243.

Köhler, J., Geels, F.W., Kern, F., Markard, J., Onsongo, E., Wieczorek, A., Alkemade, F., Avelino, F., Bergek, A., Boons, F., 2019. An agenda for sustainability transitions research: state of the art and future directions. Environ. Innov. Soc. Transit. 31, 1–32.

Langley, A.N.N., Smallman, C., Tsoukas, H., Van de Ven, A.H., 2013. Process studies of change in organization and management: unveiling temporality, activity, and flow. Acad. Manag. J. 56, 1–13.

Lee, T.W., 1999. Using Qualitative Methods in Organizational Research. SAGE Publications, Thousand Oaks (CA).

Levy, S., 1984. Hackers: Heroes of the Computer Revolution. Anchor Press/Doubleday, Garden City, NY.

Lifshitz-Assaf, H., Nagle, F., 2021. The digital economy runs on open source. Here's how to protect it. In: Harv. Bus. Rev..

Lincoln, Y.S., Guba, E.G., 1990. Judging the quality of case study reports. Int. J. Qual. Stud. Educ. 3, 53–59.
Linux Foundation, 2020. Linux Kernel History Report.
Lovell, H., 2007. The governance of innovation in socio-technical systems: the difficulties of strategic niche management in practice. Sci. Public Policy 34, 35–44.
Malone, T.W., 2018. Superminds: The Surprising Power of People and Computers Thinking Together. Little, Brown Spark, New York (NY).
Markard, J., Truffer, B., 2008. Technological innovation systems and the multi-level perspective: towards an integrated framework. Res. Policy 37, 596–615.
Marres, N., 2012. Material Participation: Technology, the Environment and Everyday Publics. Palgrave Macmillan, New York (NY).
Massa, F.G., O'Mahony, S., 2021. Order from chaos: how networked activists self-organize by creating a participation architecture. Adm. Sci. Q. 66, 1037–1083.
Mazzucato, M., 2016. From market fixing to market-creating: a new framework for innovation policy. Ind. Innov. 23, 140–156.
McAdam, D., McCarthy, J.D., Zald, M.N., 1996. Comparative Perspectives on Social Movements: Political Opportunities, Mobilizing Structures, and Cultural Framings. Cambridge University Press.
McCarthy, J.D., Zald, M.N., 1977. Resource mobilization and social movements: a partial theory. Am. J. Sociol. 82, 1212–1241.
McCarthy, J.D., Zald, M.N., 2001. The enduring vitality of the resource mobilization theory of social movements. In: Turner, J.H. (Ed.), Handbook of Sociological Theory. Springer, Boston (MA), pp. 533–565.
Meyer, D.S., Staggenborg, S., 1996. Movements, countermovements, and the structure of political opportunity. Am. J. Sociol. 101, 1628–1660.
Miles, M.B., Huberman, A.M., 1984. Qualitative Data Analysis: An Sourcebook of New Methods. SAGE Publications, Thousand Oaks (CA).
Mokyr, J., 1990. Punctuated equilibria and technological progress. Am. Econ. Rev. 80, 350–354.
Moody, G., 2001. Rebel Code—Inside Linux and the Open Source Movement. Perseus Publishing, Cambridge (MA).
Mulgan, G., 2018. Big Mind: How Collective Intelligence Can Change Our World. Princeton University Press, Princeton (NJ).
Nair, A., Ahlstrom, D., 2003. Delayed creative destruction and the coexistence of technologies. J. Eng. Technol. Manag. 20, 345–365.
Nelson, R.R., Winter, S.G., 2002. Evolutionary theorizing in economics. J. Econ. Perspect. 16, 23–46.
Netcraft, 2012. December 2012 Web Server Survey [WWW Document]. URL. Netcraft News (accessed 1.1.22). https://news.netcraft.com/archives/2012/12/04/december-2012-web-server-survey.html.
Pacheco, D.F., York, J.G., Hargrave, T.J., 2014. The coevolution of industries, social movements, and institutions: wind power in the United States. Organ. Sci. 25, 1609–1632.
Perkmann, M., Schildt, H., 2015. Open data partnerships between firms and universities: the role of boundary organizations. Res. Policy 44, 1133–1143.
Pesch, U., Vernay, A.-L., van Bueren, E., Pandis Iverot, S., 2017. Niche entrepreneurs in urban systems integration: on the role of individuals in niche formation. Environ. Plan. Econ. Space 49, 1922–1942.
Planko, J., Cramer, J.M., Chappin, M.M., Hekkert, M.P., 2016. Strategic collective system building to commercialize sustainability innovations. J. Clean. Prod. 112, 2328–2341.
Poole, M.S., Van de Ven, A.H., Dooley, K., Holmes, M.E., 2000. Organizational Change and Innovation Processes: Theory and Methods for Research. Oxford University Press, Oxford (UK).
Raven, R.P., 2006. Towards alternative trajectories? Reconfigurations in the Dutch electricity regime. Res. Policy 35, 581–595.
Raymond, E.S., 1999. The Cathedral & the Bazaar: Musings on Linux and Open Source by an Accidental Revolutionary. O'Reilly Media Inc, Sebastopol (CA).
Rip, A., Kemp, R., 1998. Technological change. In: Hum. ChoiceClim. Chang, 2, pp. 327–399.
Schot, J.W., 1992. Constructive technology assessment and technology dynamics: the case of clean technologies. Sci. Technol. Hum. Values 17, 36–56.
Schot, J., Geels, F.W., 2008a. Strategic niche management and sustainable innovation journeys: theory, findings, research agenda, and policy. Strateg. Niche Manag. Res. 7325, 537–554. https://doi.org/10.1080/09537320802292651.
Schot, J., Geels, F.W., 2008b. Strategic niche management and sustainable innovation journeys: theory, findings, research agenda, and policy. Technol. Anal. Strateg. Manag. 20, 537–554.
Schot, J., Rip, A., 1997. The past and future of constructive technology assessment. Technol. Forecast. Soc. Chang. 54, 251–268.
Schumpeter, J.A., 1942. Capitalism, Socialism and Democracy. Harper, New York (NY).
Seyfang, G., Haxeltine, A., 2012. Growing grassroots innovations: exploring the role of community-based initiatives in governing sustainable energy transitions. Environ. Plan. C Gov. Policy 30, 381–400.
Sine, W.D., Lee, B.H., 2009. Tilting at windmills? The environmental movement and the emergence of the US wind energy sector. Adm. Sci. Q. 54, 123–155.
Smith, A., 2005. The alternative technology movement: an analysis of its framing and negotiation of technology development. Hum. Ecol. Rev. 12, 106.
Smith, A., 2007. Translating sustainabilities between green niches and socio-technical regimes. Technol. Anal. Strateg. Manag. 19, 427–450.
Smith, A., Raven, R., 2012. What is protective space? Reconsidering niches in transitions to sustainability. Res. Policy 41, 1025–1036.
Smith, A., Stirling, A., 2007. Moving outside or inside? Objectification and reflexivity in the governance of socio-technical systems. J. Environ. Policy Plan. 9, 351–373.
Smith, A., Voß, J.-P., Grin, J., 2010. Innovation studies and sustainability transitions: the allure of the multi-level perspective and its challenges. Res. Policy 39, 435–448.
Smith, A., Fressoli, M., Abrol, D., Arond, E., Ely, A., 2016. Grassroots Innovation Movements. Routledge, London (UK).
Snow, D.A., Rochford Jr., E.B., Worden, S.K., Benford, R.D., 1986. Frame alignment processes, micromobilization, and movement participation. Am. Sociol. Rev. 464–481.
Steen, M., Weaver, T., 2017. Incumbents'diversification and cross-sectorial energy industry dynamics. Res. Policy 46, 1071–1086.
Tilly, C., 1993. Social movements as historically specific clusters of political performances. Berkeley J. Sociol. 38, 1–30.
Tozzi, C., 2017. For Fun and Profit: A History of the Free and Open Source Software Revolution. MIT Press, Cambridge (MA).
Tsoukas, H., 1989. The validity of idiographic research explanations. Acad. Manag. Rev. 14, 551–561.
Turnheim, B., Geels, F.W., 2019. Incumbent actors, guided search paths, and landmark projects in infra-system transitions: re-thinking strategic niche management with a case study of French tramway diffusion (1971–2016). Res. Policy 48, 1412–1428.
Turnheim, B., Sovacool, B.K., 2020. Forever stuck in old ways? Pluralising incumbencies in sustainability transitions. Environ. Innov. Soc. Transit. 35, 180–184.
Voß, J.-P., Smith, A., Grin, J., 2009. Designing long-term policy: rethinking transition management. Policy Sci. 42, 275–302.
Weizer, N., 1981. A history of operating systems. Datamation 27, 118–126.
West, J., 2003. How open is open enough?: Melding proprietary and open source platform strategies. Res. Policy 32, 1259–1285.
White, R., Stirling, A., 2013. Sustaining trajectories towards sustainability: dynamics and diversity in UK communal growing activities. Glob. Environ. Chang. 23, 838–846.
Williams, S., 2002. Free as in Freedom: Richard Stallman's Crusade for Free Software. O'Reilly Media Inc, Sebastopol (CA).
Williams, R.H., Benford, R.D., 2000. Two faces of collective action frames: a theoretical consideration. Curr. Perspect. Soc. Theory 20, 127–152.
Williams, S., Stallman, R.M., 2002. Free as in Freedom (2.0) - Richard Stallman and the Free Software Revolution. Free Software Foundation, Boston (MA).
Young, R., 1994. Interview with Linus, the author of Linux. Linux J. 1994.
Zald, M.N., Ash, R., 1966. Social movement organizations: growth, decay and change. Soc. Forces 44, 327–341.
Zietsma, C., Lawrence, T.B., 2010. Institutional work in the transformation of an organizational field: the interplay of boundary work and practice work. Adm. Sci. Q. 55, 189–221.