

# Conceptualizing market formation for transformative policy

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## ABSTRACT

Transitions are hardly conceivable without understanding how new markets are formed. However, there is still an incipient conceptualization of market formation in the context of transformation and transformative policy. Drawing on existing perspectives of market formation in economics of innovation, sociology of markets and marketing studies literature, this paper develops a framework for characterizing, differentiating and analyzing new market formation processes. We use three case studies to demonstrate how the framework is able to capture the dynamic and interconnected nature of market formation. The market formation framework serves to diagnose potential misalignments, bottlenecks and failures, to identify entry points for policy to intervene in market formation and support transformative innovation.

## 1. Introduction

Addressing grand societal challenges and the Sustainable Development Goals requires transitions to new kinds of socio-technical systems and has led to calls for transformative innovation policy (Borrás and Edler, 2020; Diercks et al., 2019; Köhler et al., 2019; Schot and Steinmueller, 2018). Transitions involve radical innovations, systemic socio-technical changes and extensive restructuring of economies. As a focal point for these dynamics, markets have been recognized as essential mechanisms for inspiring, upscaling and generalizing innovative solutions (Robinson and Mazzucato, 2019). Therefore, it stands to reason that many activities associated with transitions eventually lead to changes to existing markets and inspire the formation of new ones.

Transition studies have recognized market formation as an essential dimension (Bergek et al., 2008; Hekkert et al., 2007). Markets are commonly defined as arenas or structures that allow for and organize the exchange of products or services between sellers and buyers (Fligstein and Dauter, 2007). Market formation involves processes leading to new arenas for the exchange of products or services throughout an innovation's journey (Rip, 2012; Van de Ven, 1999).

However, how markets are formed in transitions have for long been subjected to rather cursory treatment. First, market formation is often studied in terms of which user groups to target and how to improve innovation adoption, in essence taking a diffusion perspective (Boon et al., 2020; Loorbach et al., 2020; Rogers, 2003). Such a diffusion perspective treats upscaling as an inevitable, linear process. Relatedly, innovation systemic approaches to transformative change have shown a failure in anticipating and learning about user needs. Weber and Rohracher (2012) called this a demand articulation failure and saw a necessity to take user needs and

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practices into account. Second, transition frameworks like the technological innovation system (TIS) framework apply market formation largely as a black box. For example, [Bergek et al. \(2015\)](#) demonstrate that there is lack of understanding market formation policies in the context of the underlying structures and processes of legitimization. They show that there is a need for a more systematic and differentiated conceptualization of market formation.

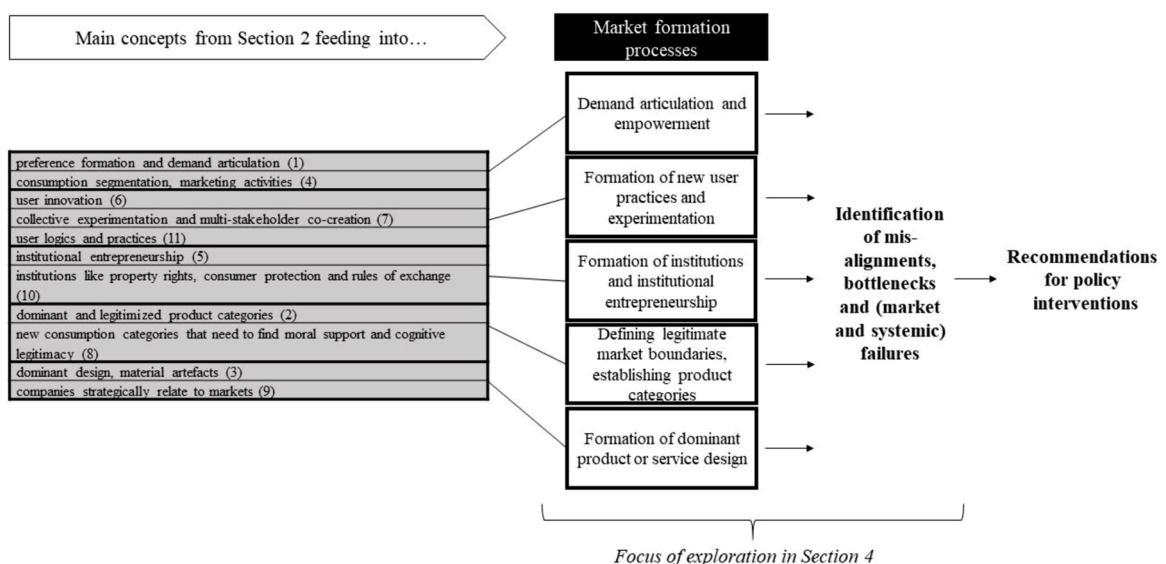
Transition studies have started to pay more attention to the process dimension of market formation ([Dewald and Truffer, 2012](#); [Hyysalo et al., 2018](#)), and the complexities and uncertainties associated with market formation that involve a wide variety of institutions and stakeholders, like firms, customers, community organizations and governments ([Schanz et al., 2019](#)). Over the last decade, efforts have been made to elaborate on end-user markets by emphasizing supporting narratives and their institutional contexts ([Dewald and Truffer, 2011, 2012](#); [Ottoosson et al., 2020](#)), as well as the notion that the emergence of markets interacts with other systemic processes such as gaining legitimacy and producing knowledge for technologies ([Binz and Truffer, 2017](#)).

With this article we want to advance and explicate this work on market formation to make it relevant for and to support policy-making in the context of transitions. We unpack the black box of market formation by differentiating five major *processes of market formation*, similar to how the ‘functions’ capture the core processes that enable technological innovation systems to emerge ([Bergek et al., 2008](#); [Hekkert et al., 2007](#)). The aim of this paper is therefore to develop a multidimensional framework for characterizing and analyzing different processes of new market formation. Disentangling these market formation processes enables the identification of misalignments, bottlenecks and failures for which transformative innovation policy interventions can then be devised.

The identification of the potential misalignments, bottlenecks and (market and systemic) failures regarding market formation serves as an entry point for transformative innovation policies. Particularly in times when the state is called upon to support and accelerate transformations, it is of paramount importance to have a thorough understanding of market formation processes and their deficiencies. Understanding the emergence of markets inevitably must be a concern for governments as they are interested in solving societal problems and are able to regulate or push market creating processes that the interplay of private actors alone cannot advance. So, we want to advance thinking about markets and already start considering markets during the emergence of technologies. We also complement and contribute to transition studies by emphasizing the demand side in market formation and sectoral policies needed for enabling the interplay between and synchronization of emerging markets, e.g. mobility-as-a-service, the sharing economy and the circular economy. Finally, our framework may also be of interest to organization and marketing studies, as these have recently addressed the role of so-called ‘moral markets’ in dealing with societal challenges and wicked problems ([Georgallis and Lee, 2020](#); [Nenonen et al., 2021](#)) and the understudied role of technology as a basis for shaping markets ([Kaartemo and Nyström, 2021](#)).

For transformative policy, while there are a wide variety of innovation types and sources that may contribute to solving grand societal challenges, new technological innovations hold great promise to contribute to the desired systemic and transformative changes. Recognizing the wide variety of possible forms of market formation, we made a deliberate choice to focus on technology-based market formation when developing our framework. We chose to focus on emerging markets that are inspired by new (applications of) technologies despite being aware of the relevant nuances related to venturing into new sectoral, demographical or geographical contexts. We did so because technological solutions often promise to shape and drive future transitions, as they have in the past ([Geels, 2002](#)). Further, we see this focus on technological innovations as a first step towards a broader understanding of market formation which would have to include new business models and social innovations that support transformations once scaled up.

We develop our framework drawing on the various streams of literature which provide diverse and complementary insights into the market formation process from different theoretical perspectives ([Section 2](#)). In [Section 3](#), we outline the conceptual framework



**Fig. 1.** Steps leading to the conceptualization of market formation processes to improve policy. The numbers in the gray box at the left-hand side indicate how this framework mobilizes the insights from the literature discussed in [Section 2](#).

comprising five major market formation processes and describe its stepwise development. We then demonstrate how the framework can act as an advanced diagnostic tool that provides useful insights into market formation processes using three illustrative cases (Section 4). We close the paper by, first, reflecting on the ramifications of our findings for transformative innovation policy that seeks to support market formation in the context of politically and societally desired transformations, and, second, outlining next steps to test and further develop our framework for analyzing new market formation processes (Section 5).

## 2. Existing perspectives of market formation

The framework we aim to develop needs to refine how transition studies deal with market formation. Our refinement was inspired by three bodies of literature that provide important foundations for transition studies (Geels, 2002): the evolutionary economics of innovation, the sociology of markets and, to a lesser extent, marketing studies. These are recognized as the main literatures that study the creation and evolution of markets (see Diaz Riu, 2012 for a review). It becomes clear that divergence and crosspollination have occurred in the way these literatures perceive markets. For example, both the sociology of markets and marketing studies build on the same sources and notions in relation to markets as narratives (Sprong et al., 2021). In the final subsection, we examine how markets have so far been incorporated into transition studies. As will become clear, these bodies of literature are complementary: they have all become interested in endogenizing market formation and recognizing similar (material, cognitive, institutional) dimensions. When presenting each body of literature, we number the main concepts adopted from it and use these concepts to build our set of market formation processes in the next section (see numbering in Fig. 1 below).

### 2.1. Evolutionary economics, innovation and markets

To explain how innovations come about, evolutionary economics has gone beyond perceiving markets as trade arenas in which buyers and sellers with rational preferences and full information maximize utility and profits. Product innovation is regarded as the result of interactive learning between users and producers, who exchange knowledge about needs and use values in so-called ‘organized markets’ (Lundvall, 1988). Markets are regarded as complex and dynamic systems in which knowledge about innovations is created, adopted and retained, and therefore as selection environments for innovations (Bleda and Del Río, 2013; Nelson and Winter, 1977).

Originally, evolutionary economics took markets for granted (Murmman and Frenken, 2006). The introduction of innovations was associated with a variety of technological options, latent demand and many suppliers. Firms sell their variant in associated niche markets, addressing a specific subset of customer segments (Saravathy and Dew, 2005) and avoiding direct competition with incumbent firms (Malerba et al., 2007). Subsequently, product characteristics become established in the form of a ‘dominant design’ (Clark, 1985; Suárez and Utterback, 1995), which also leads to homogenized customer segments (Adner and Levinthal, 2001).

Evolutionary economics then evolved and increasingly considered the demand side and interactions with users. A critical level of consensus is required about how the product should be used and which preferences are met (Benner and Tripsas, 2012). Tripsas (2008) underlines consumers’ uncertain and unarticulated preferences vis-à-vis innovations, and *preference formation and demand articulation* (1) due to, e.g. new regulations and changing consumer needs. Suarez et al. (2015) extends this cognitive dimension of markets by introducing so-called *dominant product categories* (2) that precede the emergence of a *dominant design* (3). Such dominant product categories include “the attributes, benefits, and usage conditions with which products must comply to be considered members in good standing” (Rosa et al., 1999) and draw cognitive boundaries around product markets.

### 2.2. Marketing studies

Traditionally, marketing scholars perceived markets as pre-existing spaces in which individual firms launch their products. They target consumers with differing preferences and degrees of eagerness to embrace novelty (Rogers, 2003). Firms aim to structure consumer demand through *customer segmentation* and induce preferences through *marketing activities* (4).

Recent marketing studies have explicitly moved away from the notion of markets as pre-existing exchange modes or customer segments with fixed preferences (Kindström et al., 2018). They emphasize the endogenous and open-ended nature of markets (Kjellberg et al., 2015) and view market creation as ongoing processes that actors can influence (Nenonen et al., 2019). Preferences are not static and are formed by *demand articulation* (1). Demand uncertainty decreases as product categories become coherent and legitimate and companies or governments can educate consumers about a product’s meaning and use (Doganova and Karnøe, 2015). Moreover, markets are regarded as co-evolving with institutions: *institutional entrepreneurs* (5) actively create or disrupt institutions like the rules of exchange, shared beliefs and norms (Baker et al., 2019), and market categories (Ozcan and Gurses, 2018).

A second extension of marketing studies is to advance away from the single firm-centric notion of shaping markets. Market shaping is now perceived as an inter-stakeholder activity that goes beyond firm-customer engagement (Nenonen et al., 2019). Customers and peripheral actors contribute to preference creation (Slater and Narver, 1998), sometimes even through *user innovation* (6). In some cases, companies, customers and others engage in *collective experimentation and multi-stakeholder co-creation* (7) (Kazadi et al., 2016). This aligns with Lee and colleagues’ (Lee et al., 2018; 2020) collective perspective of market creation. Such a collective view legitimizes the adoption of a more systemic perspective to markets in marketing studies (Vargo et al., 2017).

### 2.3. Sociology of markets

In the sociological literature, markets are defined as “social arenas where firms, suppliers, customers, workers, and government interact” (Fligstein and Dauter, 2007), and in which material and political activities run parallel to discursive processes of creating new frames or consumption categories that have sufficient moral support and cognitive legitimacy from consumers as well as other audiences like regulators. The *material dimension* (3) of markets takes the form of market devices, i.e. new products (Geiger and Gross, 2018). These new products shape the practices of stakeholders, such as consumers, and are part of the discursive process.

The discursive dimension emanates from the need for stakeholders to position themselves vis-à-vis markets: How do consumers perceive new products and become convinced about the value of products, and how do producers try to act on this (Fligstein and Dauter, 2007)? Consumers form functional, cultural and normative valuations of new products, in which status and familiarity play a key role. Producers reinforce the valuation of new products through “processes of standardization, cognitive anchoring, normative legitimation, and social positioning” (Beckert, 2009). Transcending individual valuation, newly forming markets are associated with *new consumption categories that need to find moral support and cognitive legitimacy* (8) from consumers as well as other audiences (Aldrich and Fiol, 1994; Navis and Glynn, 2010). Entrepreneurs actively engage in these activities by claiming the market as their own, e.g. through identity-based, meaning-making actions (Santos and Eisenhardt, 2009), or by the collective rationalization of symbolic environments in which stakeholders appreciate new meanings and identities (Rao et al., 2003).

Market formation from a sociological perspective also involves politics, as actors in markets have certain interests. Incumbent actors strive for stability in established markets, dictating how things are organized. This inherently leads to inclusions and exclusions, e.g. consumers whose needs are not met or challenger firms that struggle with existing market regulations (Fligstein, 1996). The degree of inclusiveness and malleability is treated from the perspective of markets as social constructs: spaces with boundaries which are continuously reframed and connected to things outside the space, i.e. overflows (Callon, 1998). In some cases, consumers become *empowered to articulate their demands* (1). Companies also *relate to markets strategically* (9) by starting to offer products – or terminating such offerings and creating new or destabilizing existing markets in the process. They do this together with other challenger and incumbent firms (Ozcan and Santos, 2015), governments and regulators, and societal groups (King and Pearce, 2010). Nascent markets typically feature “undefined or fleeting industry structure [...] and lack of a dominant logic to guide actions” (Santos and Eisenhardt, 2009). Actors need to build new coalitions and structures out of this uncertainty and disorganization (Geiger and Gross, 2018) by establishing *institutions like property rights, consumer protection and rules of exchange* (10).

### 2.4. Transition studies and market formation

Users, markets and distribution networks are regarded as important in transitions. For example, Kemp et al. (1998) wondered why a market for electric vehicles was so difficult to create and sustain, and emphasized the importance of market creation in the context of niches. Creating a market involves establishing rules for safety and quality requirements, property rights, liability, consumption-stimulating subsidies and tax credits for users, and competition (Geels, 2004). In the technological innovation system framework, market formation is one of the set of activities (‘functions’) that contribute to building an innovation system around an emerging technology. Here, market formation concerns mainly two dimensions: articulating who the users and their preferences are, and whether there are institutional barriers that should be overcome for markets to form (Bergek et al., 2008; Hekkert et al., 2007). In reaction to these transition perspectives that more or less start from technological development, Shove and Walker (2007) emphasize consumption activities which recombine technologies to better fit the demands of daily life. In doing so, they highlight *demand-side actors’ logics and practices* (11), and their active role in *forming use patterns and preferences* (1).

Building on this, Dewald and Truffer (2011, 2012) move away from seeing markets as pre-existing and waiting to be exploited or covered by firms in a uniform way across geographical contexts. They build on work by, e.g. Möllering (2011), who claims that we should study markets in a systemic and integrative way, not focusing on one element but taking multiple ‘devices’ into account and how they relate to other parts of the innovation system. Dewald and Truffer (2012) discern three elements that are key to market formation. The first is the ‘formation of market segments’; this concerns the identification and *building of networks of actors and institutions* (5; 9) that cover core and complementary aspects of new markets. The second is the ‘formation of user profiles’; this relates to the *articulation of user preferences* (1). These preferences should be regarded in the context of user practices and routines, social responses and status, perceptions and expectations of quality, their willingness to take risks, and their flexibility and readiness to adopt a new product and change their practices (Kemp et al., 1998; Truffer, 2003). The third is the ‘organization of interactions between producers and users’; how users and producers *organize the way they interact* (10) on the market in a regular way. This requires new rules for commodification, communication and competition to emerge and develop among users and producers (Möllering, 2011).

Recent additions to transition studies advance the active attempts by certain actors to change existing market institutions, as such acting as *institutional entrepreneurs* (5) (Pelzer et al., 2019). In addition to enabling exchange practices and proving the organization of interactions, Ottoson et al. (2020) added a cognitive dimension to market shaping by emphasizing the *construction of a narrative* on what a market is about (8). They found that there might be potential tensions between narrative building and envisioned system growth.

So far, we have identified relevant concepts in four bodies of literature. The review shows that many ideas, like demand articulation or dominant and legitimized product categories, return in different literatures, indicating that cross-fertilization has taken place. We numbered the concepts and ideas throughout Section 2 that we use as a basis for the conceptualization of market formation processes in the next section.

### 3. Building a framework based on market formation processes

From the literature streams described in the previous section, we construct a conceptual framework with market formation processes, which can be used to capture important dynamics of market formation relevant for transformative innovation policy. As we explained in the introduction, we are inspired by the notion of ‘functions’ as used in the technological innovation system framework. The gray box at the left-hand side of Fig. 1 shows how the concepts that we highlighted (and numbered) in Section 2 can be grouped into five specific and distinct processes that capture market formation. We use the key concepts identified in the grey box to define five distinct market formation processes shown in the white boxes of Fig. 1 and listed below:

- (a) **Demand articulation and empowerment:** This process defines user preferences and links them to the possibilities created by novel technologies, their applications, and the products or services they enable, reducing information asymmetries between users and producers in the process. Producers do this by defining consumption categories and pursuing marketing activities (Doganova and Karnøe, 2015). Users can also take a proactive role in demand articulation by lobbying for innovations on their terms and specifying how their needs can be satisfied with existing technologies (Dewald and Truffer, 2012; Tripsas, 2008).
- (b) **Formation of new user practices and experimentation:** This process contributes to learning and feedback when users domesticate an innovation and align it to everyday activities and practices that put constraints on how a new technology or product can be incorporated (Cherunya et al., 2020). Users like consumers and professional buyers engage in experimentation and demonstration to co-create user practices, and might even innovate themselves (von Hippel, 2005).
- (c) **Formation of institutions and institutional entrepreneurship:** This process changes the institutions that relate to and support the way in which exchanges in markets are organized, e.g. through certification, standardization, rules and regulations (Fligstein and Dauter, 2007). As institutional entrepreneurs, stakeholders can take the lead in conceptualizing divergence from existing institutions in a way that accommodates the radically new products or services or an entirely new way of applying of existing products and services and try to implement these changes (Battilana et al., 2009).
- (d) **Defining legitimate market boundaries and establishing product categories:** This process frames the boundaries of new markets as part of a socio-cognitive process performed by producers, alone or collectively, so that they align with their development and diffusion strategies (Ottosson et al., 2020). What names and narratives do they use to explain and argue for the existence of the market? This legitimization may consider the efforts of individual producers (Santos and Eisenhardt, 2009) as well as anchoring a market as a whole and establishing a distinct category (Navis and Glynn, 2010).
- (e) **Formation of dominant product or service design:** This process coordinates building dominant designs (Suárez and Utterback, 1995) that form a de facto standard for a product or service and strongly influence how a market is defined. Although dominant designs emerge once markets are maturing, the developments leading up to designs becoming prevalent start earlier, and the establishment of a design co-occurs with developments in the other four processes of market formation.

The next sections illustrate and further characterize these five processes in more detail, including the way in which they have the potential to identify misalignments, bottlenecks and failures, by exploring three cases of market formation. These cases are used to apply the framework and refine it based on these first lessons.

### 4. Exploring market formation processes in three cases

#### 4.1. Methodological approach

We applied our framework to example cases of technology-based markets in the context of transitions. This approach makes it easier to understand our conceptual arguments and see how they could be applied to empirical settings (Siggelkow, 2007). We had two objectives in doing so. First, to illustrate the defined processes and explore their suitability for capturing market formation as technologies emerge. We address the five processes in an open way without a presupposed or implicit order in mind, rather seeing them remaining in a co-evolutionary or iterative relationship. Second, to explore whether they show empirical specificities and how they identify misalignments, bottlenecks and failures in market formation.

In line with transition studies, we regard the emergence of technologies as taking place within co-created socio-technical systems, in which regulations, supply networks and infrastructures are co-developed alongside markets and technologies (Geels, 2002). We selected three cases that feature the emergence of (a coherent set of) technologies which are considered by developers, industry experts, users, etc. to contribute to a broader transition. Table 1 shows the cases by emerging technology, the transition to which they contribute, and the key references that explicate why these technologies are expected to lead to transitions.

For each case, we applied a combination of methods including interviews, document analysis, and organizing focus groups with key players. We did not, however, follow the same approach in all three cases.<sup>1</sup> Table 2 presents figures and details on the data collection methods applied in each case.

Although the three cases had dissimilar data collection methods, the document analysis (mostly based on key scientific articles and

<sup>1</sup> To ensure the framework is broadly applicable, we did not enforce a particular set of tools or methods to gather data. Instead, we argue that by defining and articulating the dynamics of interest (the five functions) and considering the particular context of the analyzed market formation case, analysts can choose their own methods, as long as they are well reasoned and robust.



**Table 1**  
Overview of the cases.

No.	Emerging technology	Contributing to transition	Refs.
1	<u>3D printing for decentralized manufacturing</u>	Transition towards green manufacturing: change from linear to circular, customized and decentralized (closer to home) manufacturing	<a href="#">Despeisse et al. (2017)</a>
2	<u>Direct-to-consumer genetic testing</u>	Transition towards personalized healthcare: change from one-size-fits-all to tailored treatments	<a href="#">Hamburg and Collins (2010)</a>
3	<u>Digital platforms for eHealth</u>	Transition towards preventive healthcare: change from cure-centered to prevention-focused care	<a href="#">Alonso et al. (2019)</a>

**Table 2**  
Data collection methods used for each case.

	3D printing for decentralized manufacturing	Direct-to-consumer genetic testing	Digital platforms for eHealth
Documents analysis	Peer-reviewed literature. Analysis of central market reports (e.g. Wohlers Reports), selected through key informant interviews and confirmed through citation analysis. Bibliometric approaches were also applied using the Web of Science, extracting the meta-data, and identifying key articles through citation analysis.	Peer-reviewed literature: key articles (see left). Additionally, we visited key company websites that were mentioned in the articles on which we searched for missions and main technologies.	Key informants from Dutch economic boards and the health ministry provided us access to key policy documents, to lists with eHealth companies (whose websites we searched), and to agendas of innovation acceleration brokers.
Interviews	Semi-structured interviews with 3D printing firms, public research organizations and users of 3D printing equipment. Interviewees were selected based on their centrality in the field (stemming from publication analysis). Participation in central 3D Printing conferences revealed other interesting interview candidates as well as providing additional insights. The number of interviews was determined by how much additional information each interview provided – in this Case 20 interviews was sufficient before diminishing knowledge returns was reached.	Semi-structured interviews with medical professionals, reimbursement agencies, regulators that were mainly approached from contacts with the Dutch reimbursement agency which has a central role. Subsequent selection based on stakeholder mapping. 6 interviews in total, lasting on average 60 min. Interviews were transcribed.	Semi-structured interviews with eHealth entrepreneurs (3 times over the course of 9 months), care organizations, innovation acceleration brokers, regional innovation agencies. Selection based on actors involved in 3 Dutch regions. 11 cases were each interviewed 2,3 times; interviews lasted on average 20 min.
Focus groups	Scenario workshop on the future of 3D printing of biomaterials. This provided insight into the state-of-the-art, needs and requirements along with expectations of how the field will unfold and challenges and opportunities ahead (as seen from key stakeholders).	Scenario workshops on the future of genetic testing in which 14 persons participated. Selection of participants based on those interview respondents who expressed interest to join. The workshops aimed at constructing future innovation pathways.	Findings were discussed in a validation workshop in which 7 persons participated who represented public investment agencies, the ministry and a few companies.
Others	Participation in standards (Joint ASTM F42 and ISO TC 261) committee meetings, visits to facilities (firms, research centers and Fablabs). Use of a number of databases (SCOPUS for bibliometrics, PatStat for patent analysis and Orbis for analysis of companies and mergers and acquisitions).	N/A	Field visits to meetings of regional innovation agencies on and with eHealth entrepreneurs and care organizations.

policy documents) as well as information gained during interviews with a wide range of different stakeholders, provided a historical perspective and knowledge of the state-of-the-art. This was laid down in a historical account that was validated in workshops, during which also anticipated future developments, challenges and needs were articulated. Triangulating the outputs of these multiple methods provided a rich and coherent overview of the emergence and potential future evolutions of the three cases. These case overviews were then examined for the market formation processes; whether these were present and how they played out. We used the operationalization presented in [Table 3](#) below to help identify the processes.

[Section 4.2](#) presents the three illustrative cases, identifying the market formation processes as the technology emerges. To help the reader, we use the abbreviations shown in [Table 3](#) to indicate where there are details related to a particular market formation process. For example, if the case refers to ‘Demand articulation and empowerment function’, we include the abbreviation [*DemandArt*]. In [Section 4.3](#) we then aim to diagnose the extent to which the identified market formation processes are associated with misalignments, bottlenecks and/or failures. Identification is based on the analysis of documents, interview data and workshops, as recounted in [Section 4.2](#). Especially the workshops were informative, as the main topic of these meetings was to investigate how and under which circumstances future diffusion would take place, starting from bottlenecks in the present.

## 4.2. Cases

### Case 1: 3D printing for decentralized manufacturing

3D printing or additive manufacturing transforms a digital 3D image into a material object through layer-by-layer ‘printing’. 3D printing can be regarded as the interplay between printing technology, materials to print with, and digital images to create a physical object. At its origin, 3D printing technology promised to accelerate product development cycles by making rapid prototypes out of plastic (Bernard and Fischer, 2002; Jacobs, 1992). A rapid prototyping R&D community emerged with its own associations (GARPA – the Global Alliance of Rapid Prototyping Associations<sup>2</sup>) and peer-reviewed journals (e.g. Virtual and Physical Prototyping Journal, and the Rapid Prototyping Journal). The shift in the use of 3D printing from rapid prototyping to direct manufacturing was driven by the maturation of key technologies as well as the increasing availability of other materials for 3D printing, such as metals and ceramics (Bak, 2003; Frazier, 2014). 3D printing enables circular, customized and decentralized manufacturing and thus has the potential to stimulate green production (Despeisse et al., 2017).

Professional users played a major role in co-developing 3D printing technologies for various niche applications. A prominent example of one of the first application areas was the proposition of customized one-off dental prostheses. Tooth prostheses were traditionally standardized, mass-produced whole teeth, tooth-covering and jaw elements. The ‘closest fit’ was selected from these standardized prostheses and then adapted to the patient’s tooth shape and jaw structure by dental surgeons through scraping, shaping, bending etc. Whilst mass-produced prostheses kept the costs of dental surgery relatively low, this also meant that the prostheses were not an optimal fit.

In the late 1990s, dentists saw a potential market for using 3D printing to make patient-specific models and surgical guides to plan and assist procedures (Gibson et al., 2006; Liu et al., 2006; Winder and Bibb, 2005). During this period of time, and because of the variety of demonstrations, dentists became increasingly interested in mass customization, and proposed various requirements in terms of consumer needs, technical standards and quality assurance. Custom implant and dental diagnosis was also being demonstrated with the use of rapid prototyping for customized dental structures: “A woman had an obvious contour deformity [...] An acrylic stent of the missing tissue was then constructed [using a 3D printer]. With the acrylic stent as guide, the graft from the iliac crest could be precisely shaped and contoured before it was attached to the mandibular angle with titanium screws” (Liu et al. 2006, p. 333) [DemandArt].

Other dentists then began experimenting with 3D printing (Scherer 2015) to create models of patients’ teeth based on medical imaging [NewUse]. This evolved into the direct printing of dental prostheses, requiring feedback loops with 3D printing professionals and new companies entering the dentistry field in order to develop additive manufacturing capabilities. One such company was Materialize (Belgium), which developed a software system (the Materialize Mimics™ software<sup>3</sup>) to translate medical imaging data into a 3D system, thereby enabling the design of dental prosthetics (Liu et al., 2006). Such support systems were essential to enable 3D printing to be effectively used for medical applications. The advent of printing with metal rather than plastic, particularly the cobalt-chrome that meets the high-quality standards of dentistry, made direct manufacturing of dental prostheses possible. De facto dominant combinations of printers, materials and design software emerged (Robinson et al., 2019) [DomDesign], which were distinct from the combinations that became dominant in other 3D printing markets, like aerospace and automotive industries (Frazier, 2014) (Fig. 2). The emerging dominant design broadened the usual practice of dental prostheses design, production and fitting, enabling dentists themselves to customize prostheses, like orthodontic models, splints and dentures, and have them available at a much quicker rate [NewUse]. This market was delineated from other 3D printing markets by the development of tailored software for designing implants, and the adaptation of 3D printers to use biocompatible materials, such as cobalt-chrome, by drawing on dentistry standards. Firms such as Formlabs (United States) played a major role in this delineation by tailoring the elements of the dominant design of 3D dentistry printing (Fig. 2) [MrktBndry]. Key firms like 3D Systems and Materialize straddled multiple markets (for example fashion, aerospace and medical prostheses<sup>4</sup>), advancing technical standards for the printers across markets, while simultaneously tailoring their products and business development accordingly. There was also a cognitive aspect to this delineation of the market, as dentists advocated tailor-made products as the optimal standard, a move which requires surgeon-designers to be responsible for the creative and skills-based part of the manufacturing process (Dawood et al., 2015) [MrktBndry]. For example, dentists such as Dr. Michael Scherer claimed that “innovation within intraoral optical scanning and 3-D printing should continue to allow clinicians to make complex procedures simpler and more efficient” (Scherer 2015, p 8).

Communities, professional societies and rapid manufacturing industry associations (for example GARPA, see above) emerged along with standardization. As 3D printing evolved and diversified, the production of end-use parts and goods triggered the need for technical interoperability, quality and safety. Direct manufacturing for mass customization required standards to be in place to guarantee that additive process technologies were compatible with existing industrial materials and computer-assisted design software. The negotiation of such guarantees started in the late 2000s with national standardization efforts in the United States, France and Germany, and were then applied across all existing and emerging 3D printing markets [InstiTrans]. These standardization efforts included the creation in 2009 of the ASTM F42 technical committee on additive manufacturing as a co-production of national standard bodies (i.e. NIST), professional societies (i.e. SME), multinational corporations (i.e. BMW, Siemens, Stryker & Honeywell), small and medium-sized firms, research universities as well as federal agencies and research institutes (i.e. NASA, Naval Air Warfare Center, Air Force Research Laboratory). Parallel to the ASTM’s efforts, from 2010 onwards, European standardization bodies, such as the French

<sup>2</sup> <https://wohlersassociates.com/GARPA.html> (accessed 15/12/2021)

<sup>3</sup> <https://www.materialise.com/en/medical/mimics-care-suite> (accessed 15/12/2021)

<sup>4</sup> <https://www.materialise.com/en/industries> (accessed 15/12/2021)

**Table 3**

Sensitizing concepts for the operationalization of the market formation processes.

Abbreviation	Processes	Sensitizing concepts
(a) DemandArt	Demand articulation and empowerment	Iterative, inherently creative process in which users try to explain what they perceive as important preferences and characteristics in relation to an emerging innovation; active lobbying for innovations that align with user preferences
(b) NewUse	Formation of new user practices and experimentation	Define and co-create the everyday context in which the innovation is supposed to be used; pilot the use of an innovation in a real-life context
(c) InstiTrans	Formation of institutions and institutional entrepreneurship	Initiate divergent changes in a field of activity, aiming to contribute to transforming existing institutions or creating new institutions
(d) MrktBndry	Defining legitimate market boundaries and establishing product categories	Demarcation process of product categories; producers aiming for control over product category; seeking legitimacy with users and governments
(e) DomDesign	Formation of dominant product or service design	Product (or service) development; defining the (core and peripheral) characteristics



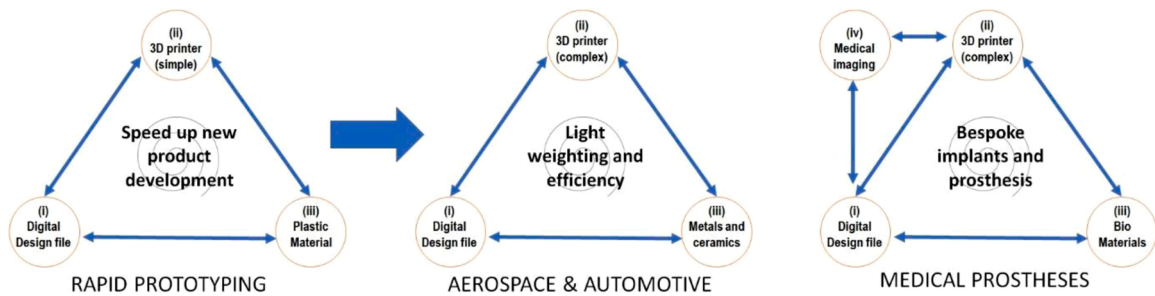


Fig. 2. The triad schema of dominant designs for 3D printing in dentistry and for two example markets.

Union de normalization de la Mécanique and the German DIN, have also supported the creation of additive manufacturing standards [InstiTrans].

At the same time, niche-specific institutions were introduced. Dental and other medical 3D printing require medically approved materials of a standardized quality and sufficient evidence on safety to support this, so that clinicians and insurance companies can make valid risk assessments. For example, the US Food and Drug Administration<sup>5</sup> started approving the use of digital patient scans in combination with software and a 3D printer in 2013 to produce patient-matched denture teeth by depositing layer upon layer of resin material (Molitch-Hou, 2013) [InstiTrans].

#### Case 2: direct-to-consumer genetic testing

‘Genetic testing’ is an umbrella term, which covers many types of tests and applications, ranging from newborn screening and carrier testing to pharmacogenetic tests. Genetic testing has seen substantial technological advances over the last 25 years. Since the Human Genome Project finished in 2003, which resulted in the first sequence of a human genome, many generations of genetic test technologies have been introduced. Numerous opinion leaders and firms like Celera Genomics had the ambition to sequence the human genome in a fast, cheap and adequate way, with “the goal of reducing the cost of human genome sequencing to US\$1000” (Heather and Chain, 2016; van Dijk et al., 2014) [DemandArt]. Cheaper testing would allow ubiquitous diagnosis and customized treatment. As such, genetic testing forms a pivotal technology in transitioning towards more personalized healthcare (Hamburg and Collins, 2010).

Parallel to the technological developments, the applications of genetic tests have changed over the years. In the Netherlands, for example, genetic testing was confined to special clinics that were established as financially separate ‘foundations’ under the umbrella of university hospitals [NewUse] due to the need for control and clinical oversight (Aarden et al., 2010). As a consequence, these clinics became highly-specialized centers for experimentation and testbeds for new diagnostic technologies (Nelis, 1998) [NewUse].

Genetic testing was soon to break out of the clinical context. Cheaper and faster tests sparked the emergence of companies that began to explore the possibilities of offering genetic tests directly to consumers, with or without the involvement of medical professionals. Two waves of direct-to-consumer genetic testing companies have since surfaced (Hogarth and Saukko, 2017). The first wave concerned firms like Sciona offering dietary recommendations based on a single (or a few) gene mutation(s) associated with nutrient metabolism. Monogenic tests were also part of this wave, like the one offered by Myriad Genetics for breast cancer predisposition genes BRCA1/2. The second wave appeared from 2007 onwards and consisted of companies that began making use of next-generation sequencing technologies, enabling polygenic risk tests for common diseases [DomDesign]. A direct-to-consumer genetic testing sector emerged, which consisted of around 250 firms by 2016 (Phillips, 2016) featuring companies like 23andMe as flagships.

The departure from the clinical domain varied by country and for each type of genetic test. Customers had become increasingly “interested in taking control of information and decisions related to their health” (interview result). This empowerment of individuals tied in with using direct-to-consumer predisposition tests for common diseases without clinical oversight [DemandArt]. At the same time, our interviews and workshops revealed that clinicians might still be involved considering that the outcomes of genetic tests would lead consumers to general practitioner’s offices for explanation, treatment or consolation, increasing the burden on healthcare systems (Boon et al., 2015). A new ‘workflow’ arose in which customers received test kits delivered to their homes, which they should return by mail, after which communication took place mostly online [NewUse]. An online culture of users then emerged, in which the use of the product is shared, e.g. through company-endorsed ‘spit parties’ on online platforms [NewUse]. Companies like from e.g. Navigenics or 23andMe approached customers, emphasizing the narrative of creating social bonds or exchanging gifts (Harris et al., 2013) [DemandArt].

Obviously, these companies and their investors saw the healthcare sector as the main area of application. They focused on carrier testing for monogenic diseases like cystic fibrosis or sickle cell disease, and pharmacogenetic tests that show individual drug metabolism characteristics to guide drug dosage decisions. These tests became standardized [DomDesign], cheap and widespread and, in many countries, sold and used under the guidance of medical specialists or pharmacists. Companies boosted expectations of polygenic risk tests that look for combinations of susceptibility alleles that are associated with a disease and can be used to predict whether an

<sup>5</sup> <https://www.fda.gov/medical-devices/products-and-medical-procedures/3d-printing-medical-devices>

individual will develop it in the future [*DemandArt*]. The FDA and medical professionals question the predictive accuracy of such tests. They call for “sufficient clinical validity” [*DemandArt*] and for complementing genetic testing with professional counseling [*NewUse*].

Commercial genetic firms like 23andMe have found it difficult to align their business models with the practices and regulations of the healthcare sector that “is based on hard evidence following from clinical studies”. Whether this is due to the ‘act first, ask permission later’ attitude of start-ups or whether they were simply unfamiliar with the institutional demands in healthcare (Bensinger, 2016), the fact remains that such firms came under the regulatory scrutiny of the FDA when entering the market. For example, after its foundation in 2006, 23andMe began offering genetic tests to give health advice. This soon attracted the attention of the FDA, who demanded evidence for the safety and efficacy of such tests. When no such evidence was forthcoming, the FDA ordered the company to stop marketing its product in 2013. The company acknowledged that they had failed to comply with regulations, and started investing in evidence gathering and reporting (Hayden, 2017) [*InstiTrans*]. The story of the struggle of digital-based health companies with regulatory oversight is not limited to 23andMe, but applies to many others as well (Steinberg et al., 2015).

23andMe and other commercial genetic testing companies survived by diversifying into and creating new (sub-)markets [*MrktBndry*]. Most closely related to healthcare is the wellness market, in which advice on nutrition and exercise, for example, can be based on genetic traits. Companies such as Helix advertised the application of such tests to those particularly interested in a healthy lifestyle and sports, e.g. related to “muscle composition”. Another market was formed for people wanting to know more about their ancestry, familial proximity, talents and character. Here, companies like Ancestry anticipated consumers’ growing interest in identity and race, which has been reinforced through popular culture and social media (Marcon et al., 2021) [*DemandArt*]. By focusing on lifestyle and ancestry, the companies were able to distance themselves from making health claims, which made clinical evidence and regulatory licenses less important [*MrktBndry*].

### Case 3: digital platforms for eHealth

Digital platforms for telehealth are part of a group of technologies that fall under the term ‘eHealth’, i.e. IT solutions used in healthcare, which have received commercial attention since the early 2010s (Mihalas et al., 2014). eHealth innovations are associated with the promise of contributing to the transition towards preventive healthcare (Alonso et al., 2019). A wide variety of eHealth solutions, like exercise apps for wearables and web portals for remote medical consults have been created and tested across the Netherlands and beyond, indicating that a dominant design has not yet arrived. Some healthcare experts expect that one or only a few generic healthcare platforms will dominate in the future, and help to standardize the way eHealth products and services are brought to patients [*DomDesign*].

At present, small-scale entrepreneurs often start with an idea of how to improve the workflows within healthcare organizations or with patients. They base their idea on their experiences as medical professionals or as IT specialists seeing business opportunities in healthcare. In the majority of cases, the idea behind an eHealth innovation concerns tracking health-related indicators and monitoring body functions to prevent diseases developing [*DemandArt*]. Companies also propose eHealth solutions as a way to make processes in healthcare organizations or patient-doctor interactions “richer and more efficient” [*DemandArt*]. For example, one company delivers digital physiotherapy care to support patients doing exercises at home, providing information, outcome analysis and video consultation. The platform helps to fill the gap between when the caregiver sends the patient home and when the patient returns. The company would like to provide blended care, i.e. a combination of physical and digital treatments of the patient.

Most eHealth solutions are first tested in small-scale pilots, sometimes even in the form of in-hospital ‘field labs’. Scaling up seems to take place slowly or not at all (Greenhalgh et al., 2017), because of a lack of data standardization, interoperability problems, local health insurance regulations, privacy issues, and evidence of use in real-life contexts, among other reasons (Parente, 2000). As a result, such pilots often remain local, i.e. inside the hospital, as their results cannot be transferred to other localities and the eHealth solutions struggle to become sustainable beyond first-mover adopters. The innovation projects we studied revealed that patients, informal caregivers and medical professionals are not attuned to and sometimes even “conservative” about using eHealth [*NewUse*]. Entrepreneurs acknowledge the importance of involving patients through so-called ‘patient journeys’, although only during late-stage prototyping [*DemandArt*].

According to our respondents, the most prominent barrier to scale is that the regulations for reimbursement must be organized differently to enable not only supplementary but also substitution of physical therapy with the digital platform [*InstiTrans*]. Health insurers do not yet reimburse this, which is partly due to the conditions set by the government as well as the way in which the professional association defines good clinical practice [*NewUse*].

Despite difficulties in scaling, there seem to be three established ‘exit routes’ that we distinguished in the innovation projects we studied: direct-to-consumer (e.g. measuring personal health through simple indicators on a mobile phone app), one mediated and sanctioned by medical professionals (e.g. the physiotherapy platform), and platforms at the level of healthcare organizations (e.g. taking the form of patient information systems). These routes seem to indicate three separate (sub-)markets, each with their own rationale: direct-to-consumer focuses on health-conscious consumers, whereas doctor-mediated and platform-based eHealth products are often part of established diagnostic and therapeutic workflows [*MrktBndry*]. The routes also reflect the respective regulations and norms: direct-to-consumer products are paid for by consumers, e.g. through app stores. The doctor-mediated eHealth products must be integrated into the standard care and guidelines of medical professional associations to become eligible for health insurance reimbursement. Inclusion in such guidelines requires gathering data on efficacy and safety [*InstiTrans*]. Companies struggling with legislation and regulations sometimes try to change these rules and norms, especially when medical professional associations have vested interests in not including eHealth products in their guidelines and may have an “inhibitory effect” [*InstiTrans*].

### 4.3. Market formation functions as a diagnostic tool

We are interested in diagnosing misalignments, bottlenecks and failures when technology-based markets emerge in the context of transitions. Based on the three described cases (see [Appendix A, Table A.1](#) for a comparison of cases with the market formation functions), we answer three questions to explore to what extent our framework is able to come to such diagnosis.

**First, are the market formation processes distinct and comprehensive enough?** The processes point to distinct issues about emerging markets. The ‘Demand articulation and empowerment’ process shows how various actors, especially companies, consumers, and industry experts, advance ideas and preferences about products/services. Often, these ideas take the form of shared broad expectations. In some cases, these demands are contested (genetic testing). ‘Formation of new user practices and experimentation’ organizes how products/services are embedded in everyday life or professional workflows. Users often interact with suppliers (3D printing in dentistry; eHealth) or companies predefine how workflows should be organized (genetic testing). With respect to ‘Formation of institutions and institutional entrepreneurship’, all three cases show companies fighting the vested interests of incumbent companies or professions. Companies are mostly involved in pro-actively ‘Defining legitimate market boundaries and establishing product categories’ as a way to create moral support and legitimacy. The three cases show the definition of new ‘exit routes’ (eHealth) or diversification into, and creation of narratives about various possible markets (3D printing; genetic testing). The ‘development of dominant designs’ process focuses on the development of a de facto standard for an innovation. The cases show that this concerns technologies as well as ancillaries, service provision channels, workflows, etc. One could view this as an architecture, platform or configuration that develops around the technology and consists of modules open to further development and variation, as was the case with the printer-materials-software model in 3D printing.

Whether the set of five processes is comprehensive enough is difficult to tell, because there might be ‘unknown unknowns’. However, although the methodological approach always included open questions that could have gone beyond the five processes, in no case did we find aspects of market formation that were not covered by the five processes. At the very least, we can say that the processes in combination cover all the relevant aspects identified in the data.

**Second, to what extent do the functions resonate and/or interact with each other?** The cases showed a number of interactions between processes. To give some examples, vested institutions in existing markets lead companies to redefine the markets they want to address and create new markets. For instance, commercial genetic testing did not gain a foothold in healthcare markets and needed to diverge into lifestyle platforms and ancestry testing. The boundaries were defined subsequently with the help of the demands that had been articulated. The 3D printing case showed that the emergence of a dominant design simplified the use of and experimentation with 3D printing, which led dentists to co-create new solutions and practices.

To go one step further, not only do the activities related to the processes interact, they seem to do so in a certain order, underlining the dynamic character of emerging markets. For example, all three cases had to deal with strict regulations and norms invested in by incumbent companies and professions. Re-articulating preferences and expectations, experimenting and developing workflows and practices, and diverging and (re)defining markets led to either incorporation or circumventing existing institutions. However, it is not possible to infer any dominant logic of function interaction from these three cases.

**Third, does the framework of market formation functions indicate particular misalignments, bottlenecks and failures?** The cases demonstrate how the framework can identify and differentiate misalignments, bottlenecks and failures in the market formation process. We presented the (potential) failures and policy interventions in [Appendix A, Table A.1](#). In general, they include non-diffusion of practice beyond certain pilots (eHealth), difficulty in re-orientation of the profession (3D printing; genetic testing; eHealth), misalignment between expected vs. offered quality standards (genetic testing; eHealth), using legitimization efforts and market boundaries to push for solutions that are ill-aligned with societal interests (genetic testing), and questions about who should reimburse the product (eHealth). Although in the Appendix we indicated the potential failures per market formation process, it is clear that failures may result not from one distinct process, but – as indicated in the previous paragraph – from an interplay between those processes. For example, dealing with strict regulations and subsequent (re)creation of market boundaries, practices, etc. indicates a misalignment.

Based on the explorative comparison, we close by discussing the market formation functions and their use in a functional framework for characterizing and analyzing different processes of new market formation in the context of transitions.

## 5. Discussion

The purpose of this paper was to develop a framework for characterizing and analyzing processes of new market formation in the context of transformative innovation policy. We use the three questions posed in the previous section to discuss the proposed framework.

First, based on the explorative and illustrative cases in the previous section, we showed that the *five market formation processes are distinct* to a certain extent. Of course, some events are difficult to attribute as they might cover more than one process. Still, the processes allow for tracking market emergence in a more detailed way and analyze emergence with distinct and differentiated, yet intertwined questions. Questions for further research would be whether the list of market formation processes is complete, or requires further elaboration. For example, one could make a case for a stronger link between ‘defining legitimate market boundaries and establishing product categories’ and the construction of visions and missions in the context of the transitions that these markets are part of ([Hekkert et al., 2020](#); [Markard et al., 2016](#)).

Second, the cases indicate patterns of events underlying the market formation processes in emerging markets. In general, we might be able to plot the occurrence of activities representing the five processes over time, accounting for and emphasizing the dynamic side

of market formation. This would also open up work on the timing of policy interventions for market formation. Importantly, there is no natural order or linear stage model implied by the five processes, neither is there a dominant process that serves as an obligatory passage point. However, the cases do show how the manifestation of certain processes subsequently influences the form and dynamics of further processes. For example, we have seen that demand-side institutions like professionals, norms and reimbursement criteria are hindering the formation of new markets, which requires increased efforts of demand articulation and the re-orientation of market boundaries. Such patterns seem to point to chains of events, reflected in the market formation processes, which reinforce themselves and lead to positive or negative outcomes. These functions interact and may form virtuous or vicious cycles (Hyysalo et al., 2018; Ottosson et al., 2020) and even ‘waiting games’ or Catch 22 situations (Robinson et al., 2012). It will be useful to study successful and unsuccessful market formation with the five processes framework in order to identify these emerging patterns.

Besides the patterns, in all three cases, we saw that markets are not formed in isolation. Actors might strategically move to adjacent markets or are influenced by developments (e.g. emerging dominant designs) in neighboring markets. Markets are inter-linked in wider ‘ecologies of markets’ and acknowledging this has broader repercussions for transition studies, as transitions are an interplay of multiple, intertwined market formations, as in the case of the circular economy. The important lesson here is that markets are not isolated, institutional arrangements, but emerge in a context of rival or complementary production and use contexts (Schanz et al., 2019). Furthermore, the notion of markets could be broadened to include other ways of exchange that are based on public or non-monetized transactions (Nelson and Winter, 1977) and include alternative, informal, community-based environments (Feige, 1990; von Hippel, 2005).

Our cases already show how the five processes framework allows a differentiated understanding of how emerging markets interact with other markets. For example, demand articulation in commercial genetic testing for healthcare purposes resonated with demand articulation in the lifestyle and ancestry markets, and, as we have seen above, institutional pressures led companies to sidestep into these lifestyle and ancestry markets. Applying our framework will enable us to delve into these patterns of market formation and interaction with other markets in the future. Since we only applied the processes to three cases, the next step should be a more widespread application of the framework to a larger number of case studies, both emerging and retrospective ones, and the aggregation of the findings.

As we have mentioned in the introduction, in this contribution we have restricted ourselves to a technology-based market formation. Of course, non-technology-based market formation may also play a key role in transformative change. To elaborate on this point, one could explore how the non-technical sources of innovation, such as social innovation and organizational innovation, may lead to new market formation, for example in relatively new markets such as the sharing economy, certified organic food markets and emissions trading. We suggest that the market formation processes developed and demonstrated in this paper will be useful for analyzing non-technology-based markets, however, we also agree that further work is needed to explore whether further processes, not visible in technology-based market formation, are at play and will have to be conceptualized. This is a line of enquiry, which we will pursue.

Third, as we have argued, market formation processes can reveal constellations and circumstances that are detrimental to the emergence of markets in transitions. Being able to pinpoint *misalignments, bottlenecks and failures opens up opportunities for dedicated transformative policy* to overcome them. We located our article in the broader discourse of transformative and systemic change and the role of policy (Schot and Steinmueller, 2018). We started from the perspective that the grand societal challenges require transformative changes that cannot take place without the formation of new markets. It is the increasing policy emphasis on market shaping and creating, as opposed to market fixing (Robinson and Mazzucato, 2019) that necessitates a deeper understanding of market formation processes, and possible policy interventions. Even where markets seemed to emerge without any deliberate public policy intervention, as was the case in many digital transformation innovations such as ridesharing and home-sharing, governments were still forced to intervene later on (Frenken and Schor, 2017). Therefore, it seems highly plausible that public policy must deal with market formation sooner rather than later, either to push a societally desirable technology or to steer the market more generally in a socially desirable direction. This resonates with the calls to work on “anticipating and learning about user needs”, which Weber and Rohracher (2012) marked as ‘demand articulation failure’ in the context of tackling grand societal challenges, and on promoting demand-side innovation policy measures (Boon and Edler, 2018; Edler and Georghiou, 2007). In consequence, there is a need for a framework to trace market formation from early stages of technology emergence onwards and in real-time, to preconceive what these technologies mean for niche but also future mass markets.

We can now turn to what our concept means for policy. A major role for transformative policy is to help reduce uncertainty for all market actors across all five functions, to create transparency, to support directionality, discourse and interaction, and to provide regulatory frameworks that are flexible enough to allow further adjustments in the formation process, but provide sufficient stability for potential producers and users. We propose that based on our market formation concept, one can underpin transformation-oriented innovation policy with a more systemic understanding of market formation processes and a thorough diagnosis of potential misalignments, bottlenecks and failures. Those dysfunctions of the market formation processes then present entry points for policy intervention.

The more public policy seeks to steer innovation and market formation in a specific direction, the more important it is to understand the subtleties of market formation across the five functions in order to tailor intervention accordingly. So far, the market and innovation uptake diagnosis is often poor and the focus is mainly on lowering the price for innovative technologies through subsidies and tax reductions (Edler, 2016). However, as we have shown in this article, the market formation process and associated misalignments, bottlenecks and failures are much more complex and differentiated than too high costs for an innovation. As for policy intervention measures, we present some examples in Appendix A, although they are not based on rather than inspired by our cases. These examples demonstrate that the toolbox of demand-side innovation policy (Creutzig et al., 2018; Edler and Georghiou, 2007; Edquist and

Hommen, 1999) and related policy instruments could thus be further developed and tailored more effectively to specific market formation circumstances.

Potential directions for policy intervention to be developed follow from the five market formation processes. A slow innovation uptake can, for example, be caused by a *poor articulation of demand* in early stages, thus hampering the design of technological solutions that are much more in line with market expectations. Anticipating future demand and supporting its articulation may thus be the most appropriate policy intervention. One can imagine process-informed foresight to help anticipate the future market challenges around competing and potentially disruptive technologies. Equally, slow market formation can have its roots in the *poor adaptation of user practices* caused by deeply embedded practices and lack of awareness of the positive benefits of a new technology. Here, in addition to awareness raising and training measures, experimentation moderated and supported by the state would be required to challenge users and enable them to learn. Further, new regulations may be needed to establish novel workflows. In this context, new technologies often raise concerns about what constitutes this new market, what the normative standards and the *legitimacy of market boundaries* are. Policy interventions here would have to focus on an open and transparent discourse about the concerns and hopes associated with technological innovations and the transition they support, leading to a higher level of acceptance or further modifications in order to increase their legitimacy. Often, the demarcation of legitimate market boundaries resonates with *institutional configurations in existing markets* that may hamper the coming together of new demand and new supply. This may be especially the case if technologies are characterized by a high level of complexity and thus a high level of uncertainty in terms of which actors are entitled to which parts of the market. This necessitates regulatory clarifications on property rights and the rules of exchange, potentially accompanied by regulatory sandboxes to allow for the development of appropriate regulation. This is strongly related to the *establishment of dominant designs* that will shape the final market. Often, this happens through market forces alone in forming de facto standards. However, the state may intervene in order to speed up this process, influence the direction of standardization and ensure de facto standards are in line with the regulations that shape market formation as a result of the market formation discourse. The development and deployment of dominant designs can be pushed through public procurement. In the appendix, we illustrate the demand-side bottlenecks and possible policy interventions along our three cases. These illustrations show how the five functions can be used separately or in combination to guide policy intervention that supports market formation.

## 6. Conclusions

Our approach to market formation is informed by complementary theoretical perspectives. By combining these perspectives in a functional framework covering five market formation processes, we are able to advance the study of market formation in the context of transformative policy. The advancements are in line with calls for taking a process perspective (Dewald and Truffer, 2012), for opening the black box of emerging markets (Bergek et al., 2015) and especially elaborating on the demand-side of markets which is currently under-addressed in transformative innovation policy (Weber and Rohrer, 2012). The framework enables us to capture the systemic, contextualized nature of market formation processes from early phases of technology emergence onwards, and can use this to study and design market-shaping policies that contribute to desired transitions. This, then, could become an essential element to meet the ‘operational intelligence requirements’ which have been diagnosed as major prerequisites for appropriate and legitimate policies to support demand and market formation in the context of transitions (Boon and Edler, 2018).

## Declaration of Competing Interest

None.

## Appendix A

Table A.1.



**Table A.1**

Comparison of cases with the market formation functions.

	1. 3D printing for decentralized manufacturing	2. Direct-to-consumer genetic testing	3. Digital platforms for eHealth
<i>Demand articulation and empowerment</i>	Improvements in speed, accuracy and cost in 3D printing for rapid prototyping generated interest among professional users in various sectors, e.g. dentistry. They are interested in mass customization, based on different requirements in terms of consumer needs, technical standards and quality assurance. <b>(Potential) failure:</b> development of technologies following demands of (too) select group of active surgeon-designers. Some preferences might become overlooked, e.g. in relation to green manufacturing. <b>Policy:</b> reduction of information asymmetries through awareness campaigns and process-informed foresight.	Producers strove for fast and cheap tests and branded their products as making healthcare more personalized and empowering individuals to take control of their lives in terms of disease susceptibility and prevention. Clinicians asked for clinical validation. <b>(Potential) failure:</b> technology providers fail to understand the performance expectations of users, in particular because users (consumers, healthcare professionals) have different preferences. <b>Policy:</b> early, interactive development of performance standards that meet medical (evidentiary) standards.	Entrepreneurs often have their own ideas, which in some cases originate in their own experiences as medical professionals. They acknowledge the importance of involving patients, but organize e.g. so-called ‘patient journeys’. The articulated benefits include disease prevention (for consumers) and making patient-doctor interactions more efficient (for healthcare professionals). <b>(Potential) failure:</b> co-generation of expectations between diverse groups of users and suppliers of new technologies not taking place. Especially not on the level of understanding of underlying values and norms. <b>Policy:</b> organizing processes of mutual expectation management.
<i>Formation of new user practices and experimentation</i>	Dentists began experimenting with rapid prototyping with specialized materials for teeth (metals and ceramics) for customized prostheses. This required feedback loops with 3D printing professionals in order to develop the required additive manufacturing capability. 3D printing enabled dentists to customize prostheses themselves. <b>(Potential) failure:</b> joint user-supplier experimentation in a late stage of the technology development to define the optimal functions of the innovation in different user contexts, in protected spaces if needed. <b>Policy:</b> regulatory sandboxes and public demonstrators.	Genetic tests were offered directly to consumers without involving clinics. This triggered new forms of interactions between test providers and users without the involvement of the medical profession. An online culture of product users has emerged. Clinicians find it important to complement testing with professional counseling. <b>(Potential) failure:</b> as on the left, plus: quality control in area of sensitive technologies (health and safety, ethical considerations). <b>Policy:</b> as left, plus regulatory bodies and professional bodies must be mobilized to identify any regulatory issues early on to prevent misaligned technology been rolled out with negative market creation effects.	Pilots play a major role but often remain local; pilot results are not transferred to other localities and pilots struggle to become sustainable after first-mover adopters; practices of patients, informal caregivers and medical professionals are not attuned to and sometimes even conservative about using eHealth; training is needed and they need to redefine what ‘good care’ is. <b>(Potential) failure:</b> lack of scaling up and diffusion of innovative solution. Poor competencies on the user side and cultural and practice ‘lock-in’. <b>Policy:</b> awareness raising initiatives, user training, demand subsidies to cover learning costs with users.
<i>Formation of institutions and institutional entrepreneurship</i>	Communities, professional societies and rapid manufacturing industry associations emerged along with standardization. Regulation discussions on manufacturing end products, e.g. regulatory approval, IP-issues related to the design files. 3D printing standardization is occurring above and across the individual, product-focused markets. <b>(Potential) failure:</b> techno-centric standardization processes may favor certain preferences or design criteria. This may lead to creation of markets that do not align well with societal goals like sustainability. <b>Policy:</b> state support of standardization activities, early involvement of state regulatory bodies.	Companies struggle with regulatory authorities as they see genetic testing as a new market space that should not be governed by healthcare-related regulations. Regulatory agencies and clinicians uphold strict regulations and norms. Companies more or less comply with norms. <b>(Potential) failure:</b> existing regulatory framework and regulatory practices hinder new practices and adoption of personalized medicine. Path dependencies deter innovative adopters. <b>Policy:</b> awareness within regulatory bodies concerning their responsibilities for adjusting regulation and engaging with emerging market actors.	Companies struggle with legislation and regulations, especially with arranging reimbursement for eHealth innovations, flaws in the real or perceived rules, and becoming part of the guidelines of medical professional associations. Many entrepreneurs are trying to convince institutions to change; only some are successful. <b>(Potential) failure:</b> existing regulatory framework is not able to accommodate preventive medicine innovations. <b>Policy:</b> create regulatory sandboxes and/or alternative reimbursement schemes for preventive measures.
<i>Defining legitimate market boundaries and establishing product categories</i>	3D printing has matured into a number of sub-sectors: dentistry and prosthetics, unique 3D shapes in the automotive and aerospace industry, etc. The customized approach allows dentists to display their creativity and craftsmanship. <b>(Potential) failure:</b> the division of responsibilities becomes vague: what is the remit of 3D printing companies and of dentists? And does this lead to the	Companies are striving to create a new market for genetic consumer tests that cover multiple, related services, ranging from disease propensity to ancestry information. They actively differentiate these from healthcare. <b>(Potential) failure:</b> innovation solutions are trapped in their original niches, lack of spread of user value across different potential areas and	There are three major strategic market ‘exit routes’: direct-to-consumer, mediated and sanctioned by medical professionals, and arranged at the level of healthcare organizations. The choice of route dictates to a large extent how other market formation functions play out, e.g. what regulations are applicable. <b>(Potential) failure:</b> each type of market pathway has downsides regarding

(continued on next page)

Table A.1 (continued)

	1. 3D printing for decentralized manufacturing	2. Direct-to-consumer genetic testing	3. Digital platforms for eHealth
	erosion of the dentistry profession? <b>Policy:</b> through healthcare quality inspectorates division of tasks can be guaranteed.	sectors. <b>Policy:</b> together with producers and users co-create a narrative around personalization.	upscaling potential and/or expected revenues. <b>Policy:</b> a tailored preventive healthcare pathway should be established and legitimized, e.g. requiring new regulations.
<i>Formation of dominant product or service design</i>	The dominant design is the triad interplay of printing technology, materials and digital design with specific requirements based on the respective subsectors (dentistry, automotive etc.). <b>(Potential) failure:</b> there is no dominant product or service emerging, the lack of which opens up questions on how policy could intervene in 3D printing. The analysis suggests that perhaps a focus on application-centric 3D printing is more appropriate than techno-centric 3D-printing (focusing on the printers). <b>Policy:</b> state regulation and procurement can push for dominant designs, but with caution and right timing, not closing down variety.	Next-generation sequencing technologies now enable polygenic risk tests for common diseases. The testing service has emerged with a clear digital component: communication with customers is done via websites, information is conveyed through online tutorials, and test kits are home delivered. The ‘workflow’ and distribution of activities between company and customer have become standardized across the industry. <b>(Potential) failure:</b> a few of the manifold processes, competencies and infrastructure items to be in place for a solution become a dominant design that works in the market place. <b>Policy:</b> state to analyze the needs for the development into dominant design roll out and tackle deficiencies.	There are many eHealth solutions that have been created and tested across the Netherlands and beyond, indicating that a dominant design has not yet arrived; some expect a more encompassing and generic healthcare platform to arrive in future. <b>(Potential) failure:</b> who is leading (and benefiting from) standardization? Public, private and professional lead-outs all have their downsides, e.g. in terms of accessibility for new players. <b>Policy:</b> attempt to create an open-access platform that ensures a level-playing field.

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