An Assessment of the Cultivated Meat Innovation System
in the USA and Europe

A thesis submitted in partial fulfilment
of the requirements for the degree

Master of Science
(M.Sc.)

in

Industrial Ecology

written by

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Executive Summary

This thesis compares the state of the cultivated meat (CM) industry in the USA and Europe. To do so, extensive desk-research was conducted, summarising existing data, and 21 interviews with CM experts were held. The result is an analysis comprised of both quantitative and qualitative data. In this thesis, the CM industry was understood as technological innovation system (TIS), a framework often used to analyse emerging industries. To compare the state of the CM industry in the USA and Europe, three research questions were answered. The first was: *What is the structure of the cultivated meat innovation system, specifically its technology, actors and networks, and institutions?* To answer this research question, a review of CM's technology, an overview of actors and their associated networks and of the institutions governing CM is provided. The answer to this research question is in summary that CM is a nascent technology with many uncertainties from a technological standpoint, that its actor networks are still emerging, and that the regulatory framework is relatively clear in both the USA and Europe. The second research question was: *How does the functional performance of the cultivated meat innovation system compare in the assessed regions?* To answer this research questions, seven functions provided by the TIS framework were analysed. These seven functions are argued to influence the development of an innovation in a given region, and comprise for instance Knowledge Development and Diffusion, Entrepreneurial Activity, or the Venture Capital Availability. The answer to this research question is in summary that the USA is leading across all assessed indicators. The CM industry is clearly leading in the USA over Europe. The only indicator on which Europe is leading is public research output on CM. The third and last research question was: *What themes with importance to the near-time development of the cultivated meat industry can be identified?* To answer this research question, a thematic analysis was applied to the interview content that could not already be understood through the lens of the TIS framework. The answer to this research question is in summary that there are two important challenges for CM: the development of its technological system, and the development of its supply chain. For the technological system, specifically, the main challenge is to reduce costs. For the supply chain, interviewees identified the development of a work division in the industry of high importance, although this appears to be already partially under way. After presenting the results, an extensive discussion is provided. Two points of the findings are particularly worthwhile to point out. Firstly, the dominant role of the USA compared to Europe. Although this thesis indicates that the USA is clearly leading compared to Europe, the results should not be overinterpreted. The number of CM start-ups in both regions is identical, although the US' start-ups appear more advanced; and, as already mentioned, the public research output is stronger in Europe. Whether the CM industry will actually be focused in the USA remains to be seen, and the dices have not yet fallen. Secondly, there appears to be an "technology battle" between plant-based meat (PBM) and CM upcoming. In this context, it may come that PBM will evolve as "dominant design" for unstructured 2D products, such as burger patties, while CM may evolve as "dominant design" for structured 3D products, such as steak. Yet, this poses the challenge to create CM for 3D products in a cost-efficient way in a not too far future. However, the development will not be deterministic, and maybe one will observe entirely different pathways, for instance with hybrid products of PBM and CM. The main limitation to this work is the usage of the TIS framework, which is not yet quantitatively validated. A key avenue for future research lays in creating a computational model for the development of the CM industry, for example an agent-based model. This work makes contributions from both an empirical and a theoretical angle. From an empirical angle, it sheds light on the CM industry in the USA and Europe; from a theoretical angle, it provides an example of an international, comparative TIS analysis. Lastly, recommendations to policymakers and CM companies are given. Which world region will come to dominate the CM industry remains to be seen. But the assessment at hand indicates that it may yet be again the USA, which came to dominate many emerging technology-driven industries in recent years.

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Table of Abbreviations

CAGR	Compound Annual Growth Rate
CM	Cultivated Meat
EFSA	European Food Safety Authority
EIT	European Institute of Innovation & Technology
FDA	Food and Drug Administration, part of US Department of Health and Human Services
FSIS	Food Safety and Inspection Service, part of US Department of Agriculture
GRAS	Generally Recognised as Safe
GHG	Greenhouse Gas
GDP	Gross Domestic Product
IE	Industrial Ecology
IPO	Initial Public Offering
IS	Innovation System
IP	Intellectual Property
MLP	Multi-Level Perspective
NGO	Non-Governmental Organisation
PBM	Plant-based Meat
R&D	Research and Development
STEM	Science, Technology, Engineering and Mathematics
SNM	Strategic Niche Management
TIS	Technology-Specific Innovation System
TM	Transition Management
USA	United States of America
VC	Venture Capital
WWF	World Wide Fund for Nature

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1. Introduction

Meat consumption accounts for approximately 10% of global annual greenhouse gas emissions (FAO, 2017) and is therefore a key driver of climate change. For reducing these emissions, one proposed strategy is to shift to more plant-based and meat-reduced diets (Dagevos & Voordouw, 2013; de Boer et al., 2014). Another prospect for an emission reduction is a substitution of conventional meat by meat alternatives (or: meat analogues) (Chatham House, 2019; WEF, 2019a). Meat alternatives promise comparable sensory qualities as conventional meat, yet with less adverse side effects such as environmental pollution. Since meat alternatives strive for meat mimicry, they typically cater to meat eaters, not vegetarians or vegans (Chatham House, 2019; WEF, 2019a). Important examples of meat alternatives are insect-based meat, plant-based meat, cultivated meat, [1] and hybrid meat, a mixture of the aforementioned.

The focus of this work is cultivated meat (CM). CM is meat that is made by placing animal stem cells in an appropriate medium and growing them directly into the desired forms, without stockbreeding (Post, 2014; Post & Hocquette, 2017). CM is one example of “cellular agriculture”, versus *animal* agriculture (Mattick, 2018), an approach that entails also for instance cultivated seafood, milk, leather, or horn. Cellular agriculture and CM are both applications of biotechnology. In comparison to other meat alternatives, CM is biochemically identical to conventional meat, and could therefore offer identical sensory qualities as conventional meat (Stephens et al., 2018).

CM is predicted to have substantially lower greenhouse gas emissions than conventional meat, provided the electricity for production stems from sustainable sources (Alexander et al., 2017; Lynch & Pierrehumbert, 2019; Tuomisto, 2018). Other potential benefits include reduced animal suffering, since CM will eventually most likely not require the harming of animals, and a better human diet, for instance because CM may not carry antibiotics residues (Kadim et al., 2015; Mattick, 2018). Until 2040, CM is estimated to substitute up to 35% of the global meat market, reaching a total market size of $630 billion (A.T. Kearney, 2019).

1.1. Problem Statement

At the point of writing, a near-time market introduction of CM is not expected, and before this may happen several technological and regulatory challenges need to be overcome (Stephens et al., 2018). In addition, after market introduction the acceptance of CM by consumers is not assured (Bryant & Barnett, 2018).

Research on CM is aligned towards these challenges for CM. Previous studies can be categorised into three broad groups. Firstly, studies concerning the technological development of CM (see for instance Arshad et al., 2017; Gaydhane, Mahanta, Sharma, Khandelwal, & Ramakrishna, 2018; GFI, 2018a, 2019a; Specht, Welch, Rees Clayton, & Lagally, 2018). However, given the complexity of science and engineering required to bring CM to market, much relevant research occurs in sub-fields, e.g. in tissue engineering or synthetic biology, not necessarily with an explicit link to CM. At this point, the main technological obstacle for CM appears to be a reduction of medium costs (GFI, 2019f). Secondly, studies concerning regulatory aspects of CM (see for instance Barlow et al., 2015; Liu & Gasteratos, 2019; Penn, 2018; Petetin, 2014). However, the regulation of CM is moving out of academic research and is becoming increasingly an applied policy issue (Chatham House, 2019). Thirdly, studies concerning the consumer acceptance of CM, a burgeoning area of research, see Bryant & Barnett (2018) for a recent review. Studies in this area explore customer’s willingness to consume CM (Bryant et al., 2019; Slade, 2018; Wilks et al., 2019; Wilks & Phillips, 2017), how to name it (Bryant & Barnett,

[1] Also known as cultured meat, clean meat, synthetic meat, or in-vitro meat.

2019; GFI, 2018b), qualification studies such as focus groups (Lupton & Turner, 2018; O'Keefe et al., 2016; Verbeke, Marcu, et al., 2015), and experimental studies that test how a change in a certain variable affects consumer acceptance (J. Anderson & Bryant, 2018; Bekker et al., 2017; Macdonald & Vivalt, 2017; Siegrist et al., 2018; Siegrist & Sütterlin, 2017; Verbeke, Sans, et al., 2015). For a further summary and discussion of CM, the reader may refer to existing overview articles (Chatham House, 2019; Datar & Betti, 2010; Hocquette, 2016; Kadim et al., 2015; Mattick, 2018; Post, 2014; Post & Hocquette, 2017; Stephens et al., 2018).

So far, no research investigated the CM industry itself. One industry report provided an overview of CM companies and investments in them, status 2019 (GFI, 2019a). Two papers provided expert viewpoints on the future development of the CM industry (Böhm et al., 2018; Tiberius et al., 2019). In addition, some publications outline near-time challenges for the CM industry (Chatham House, 2019; Stephens et al., 2018). Yet, no research sought to understand the CM industry as phenomenon, let alone providing an account for explaining its potentially differential development by region. With this work I seek to close this research gap: to provide a better understanding of the CM industry and how it may differ by region.

1.2. Research Goal and Questions

The main goal of this thesis is to provide an assessment of the CM industry – the CM innovation system, see below – in the United States of America (USA) and Europe. Both regions are of special interest: while in the USA the highest number of privately-funded CM companies are located, status 2019, in Europe the earliest CM experiments occurred (GFI, 2019a).

For assessing the CM innovation system in the USA and Europe, this work seeks to answer the main research question: *what is the status of the cultivated meat industry in the USA and Europe?* This main research question is answered cumulatively by answering the following research questions (RQ):

RQ 1: What is the structure of the cultivated meat innovation system, specifically its technology, actors and networks, and institutions?

RQ 2: How does the functional performance of the cultivated meat innovation system compare in the assessed regions?

RQ 3: What themes with importance to the near-time development of the cultivated meat industry can be identified?

The next section described in summary how these RQs are answered.

1.3. Approach

For deciding how to analyse the CM industry, the key factor to consider is the limited availability of data. In comparison to a mature industry, for instance the automotive sector, the CM industry is at a very early stage. There are worldwide about 60 active CM companies (GFI, 2019c), and the worldwide total revenue created by CM is zero. Because of this 'low *n* situation', understanding the CM industry through quantitative methods is limited. An explorative qualitative method is more likely to yield significant results (Brady, 2011; Silverman, 2016).

An established framework for analysing an industry is the "innovation system" (IS) framework (Dosi, 2013; Edquist, 2006; Fagerberg, 2006). The framework holds than innovations generated by an industry are the outcome of a complex, collective process of a multitude of interacting and co-evolving actors. Conventionally, an "industry" is defined as a set of companies producing similar or substitute products (Cambridge Dictionary, 2019). In this work, however, an industry is conceptualised as an IS. By conceptualising the CM industry as IS, I seek to give just to the complexity involved in the production of producing CM. The reader finds more information on the IS framework in section 2.1.2. If subsequently speaking of the CM industry, I imply its conceptualisation as IS.

The IS framework exists in different variations, dependent on the focus of analysis. This work is focused on one technology: CM. The framework conventionally used for this case is "technology-specific innovation system" (TIS) framework (Bergek, Jacobsson, Carlsson, et al., 2008; Hekkert et al., 2007). An analysis using the TIS framework typically entails a structural and functional analysis. Both analyses together enable to understand the promoting and inhibiting factors for the continued development of the TIS. A TIS analysis provides a rich, detailed picture of an industry – exactly what is needed to close the identified research gap.

For the analysis, data from desk-research and interviews is used, a combination typically chosen for an TIS analysis (Bergek, Jacobsson, Carlsson, et al., 2008; Hekkert et al., 2007). The desk-research sets the stage. It provides a preliminary picture of the CM industry from existing publications and research and also includes quantitative data. The interviews complete the drawn picture and enrich and qualify it. After the TIS analysis, an inductive thematic analysis is conducted on the 'residual' data of the interviews.

1.4. Relevance to Industrial Ecology

This thesis is written as partial fulfilment for the completion of a Master of Science in Industrial Ecology (IE). IE is an academic discipline that evolved in the late 1980s and early 1990s from two early contributions by Frosch & Gallopoulos (1989) and Ayres (1989). At that time, the concept of "sustainable industrial development" (Barbier, 1987) was popularised: the idea that an economy's gross domestic product (GDP) could continue growing, contributing to societally-desired goals such as poverty reduction, while the associated environmental pollution could get reduced, contributing to the goal of environmental protection and reservation. Hence, sustainable industrial development was the idea of decoupling of economic growth from environmental pollution. The decoupling was operationalised by the idea of reducing the environmental impact per unit of GDP (Graedel & Allenby, 2010).

IE proposed that reducing the environmental impact per unit of GDP could be achieved by learning from nature: natural ecosystems recycle virtually all resources, as one organism's waste is another's organism's input (Ayres, 1989). Hence, it was suggested that in an "industrial ecosystem" (Frosch & Gallopoulos, 1989) one industrial process' waste would be another's industrial process' input. As consequence, environmental pollution could be reduced.

Researchers in IE subsequently sought to understand better where and when industrial systems pollute, and how these systems could be optimised to reduce pollution (Graedel & Allenby, 2010). Methodologically, the focus laid on understanding from a system-perspective the material and energy flows of society, following the logic of input-output analysis (Duchin, 1992).

However, it became clear that for implementing an IE also social factors need to be considered, for instance the feasibility of implementation by policy-makers (O'Rourke et al., 1996). Following this notion, IE became an inter and multidisciplinary field of research, not covering only the analysis of material and energy flows, but also how possible solutions can be designed and implemented. Hence, in summary, IE was defined as "the study of the flows of materials and energy in industrial and consumer activities, of the effects of these flows on the environment, and of the influences of economic, political, regulatory, and social factors on the flow, use, and transformation of resources" (White, 1994).[2]

The Master in IE at TU Delft and Leiden University follows this definition. It aims to teach students "concepts, methods and tools to (…) identify, design and critically evaluate sustainability solutions and their implementation" (LU/TUD, 2020). A "typical" IE thesis should accordingly focus on, among other aspects, a sustainability problem and/or solution and apply a systems perspective - integrating technological and social aspects (LU/TUD, 2019).

The thesis at hand is relevant to IE as a field of research and can be seen as a "typical" IE thesis. Firstly, the thesis has relevance to IE because CM is an innovation with a very high environmental pollution reduction potential. Much sustainability-related research in the last two decades sought to understand how consumers can be motivated to consume more sustainable products (Gilg et al., 2005; Heiskanen & Pantzar, 1997; Sanne, 2002; Tukker et al., 2017; Young et al., 2010). However, the problem remains that intrinsic decision trade-offs (Hüttel et al., 2018; Vermeir & Verbeke, 2006), for instance higher prices for more sustainable goods, result in only slowing growing demand for sustainable products. CM offers a pathway forward because, if offered price-competitively, it requires no behavioural adjustments by consumers while potentially substantially reducing emissions (Stephens et al., 2018). In other words: CM offers the potential to directly substitute less sustainable goods. CM thereby follows the fundamental logic of IE: to reduce the environmental impact per unit of GDP (Graedel & Allenby, 2010). Secondly, the thesis can be seen as a "typical" IE thesis because it applies a systems perspective and is interdisciplinary in nature. The usage of the suggested IS framework takes intrinsically a systems perspective. It covers not only the social system, but also the technological system. Moreover, it not only covers the supply side of CM (e.g. producers), but also the demand side of CM (e.g. market acceptance). In the next section, I end this introduction by providing the structure of this thesis.

1.5. Structure

The structure of this thesis is as follows. Section 2 is the background section on the used theoretical frameworks and on meat alternatives. In section 3 the methodology of this thesis is summarised. Section 4 is the first results section, in which research question 1 is answered, the structural analysis. Section 5 is the second results section, answering research questions 2 with the functional analysis. Section 6 is the third and final results section, answering research question 3 with the thematic analysis. Section 7 is this thesis' discussion, in which limitations of this work are presented, avenues for future research outlined, an overall conclusion given and implications elaborated. Additional information is found in the Appendices.

[2] IE was recently popularised through the concept of "circular economy". Circular economy proposes, as IE, that the economy should follow a closed-loop logic, eliminating waste (Korhonen et al., 2018). In comparison to IE, circular economy is a practically-oriented concept (Ellen MacArthur Foundation, 2012, 2019) aimed at implementation by businesses (Ellen MacArthur Foundation, 2015a) and policymakers (Ellen MacArthur Foundation, 2015b). The boundary between IE and circular economy is fluid (Baldassarre et al., 2019; Saavedra et al., 2018). Simplified it could be argued that IE is an area of academic research, while circular economy popularises its ideas and concepts for a wider audience.

2. Background

In this section, background information on this thesis' theoretical framework and on meat alternatives are provided.

2.1. Theoretical Framework

This section provides an account of the theoretical underpinnings of the IS framework, compares different innovation systems (IS) conceptualisations, and elaborates on the specific lenses used for this thesis: technology-specific IS (TIS). The IS framework used in this work is based on the evolutionary theory of innovation, which is described in the next section.

2.1.1. Evolutionary Theory of Innovation

The study of innovation originated from the question how economic growth is created. Conventional economic theory assumed that market processes yield an efficient resource allocation, i.e. the optimal allocation of scarce resources to welfare-maximising ends (CORE, 2017). Such an efficient resource allocation presupposed an economy in an equilibrium. However, a system in static equilibrium can by definition not yield a change such as economic growth.

Joseph Schumpeter proposed instead an evolutionary theory of economic growth (1934). He suggested that the economy is in a constant disequilibrium. Hence: resources are not always efficiently, i.e. optimally, allocated. Local market disequilibria allow entrepreneurs to create "new combinations" of resources (Fagerberg, 2006): innovations. The economy thereby functions as a self-regulating system, and the innovation process follows a similar evolutionary logic as natural selection (Dosi, 2013). Schumpeter's evolutionary theory of innovation was later extended and formalised, with important contributions by Freeman & Soete (1974) and Nelson & Winter (1982), among others, see Fagerberg, Fosaas, & Sapprasert (2012) for an overview.

The suggested evolutionary logic can be summarised as a three-stage process of *variation*, *selection*, and *retention* (P. Anderson & Tushman, 1990). At the variation stage, the "new combinations" – innovations – are introduced. These are either new *products* or *processes* (or: production technology, production processes) (Fagerberg, 2006).[3] The variety creation is not random, but shaped by anticipated market needs ("market pull") or follows what is technologically possible ("technology push") (Mowery & Rosenberg, 1979). Another factor is innovators belief in what is worth attempting – a "technological paradigm" within "normal problem solving activity" (Dosi, 1982) that pre-defines variety creation. At the selection stage, innovation are non-randomly selected by the "selection environment" (Nelson & Winter, 1977). The selection environment may impose a *market selection*, for instance the competition against substitute products, and a *non-market selection,* for instance the adherence to regulatory frameworks (Nelson & Winter, 1977). The non-random variation and selection of innovations implies that innovations follow what was called a "technological trajectory" (Dosi, 1982): the innovation process is path-dependent. At the *retention* stage, innovation's usage stabilises – innovations become the regular way of doing things.

Innovation are retained at the retention stage through the inertia of what was described as society's "socio-technical systems" (STS) (Geels, 2004; Geels et al., 2017). In a narrow definition, technology consists only of hardware (physical components) and software (ways of utilizing the hardware or knowledge to operate the hardware). In a broader definition, however, technology is thought to consist also of "orgware" (the organisation of hardware and software in a meaningful way) and

[3] More generically, innovations were also defined as "novel ideas" (Rogers, 2010). However, the term "innovation" refers in the literature typically to technological innovation, unless explicitly named differently, for instance as "social innovation" (Pol & Ville, 2009). An alternative name for innovation, following this technological definition, is "technological change" (Rip & Kemp, 1998).

"socioware" (a technology's social embedding) (Rip & Kemp, 1998). The conceptualisation of a STS gives justice to both the technological system (hardware and software) and the social system (orgware and socioware) (Borrás & Edler, 2014). The retention of innovations is explained through lock-in effects (Arthur, 1989) operating in both the technological and social system of the STS. In the technological system, retention is created by infrastructures, technology interfaces, standards etc., while in the social system retention is created by beliefs, formal institutions, informal rules, user preferences etc. (Geels, 2004). Although society's STS exhibit inertia, they are "dynamically stable" (Geels, 2004), meaning that they are temporarily stable but under continuous adaptation. The adaptation of an STS can be thought to operate through two different ways: continuous (or: incremental) innovations create improvements along "technological trajectories" (Dosi, 1982). Discontinuous (or: radical) innovations, on the other hand, yield new pathways for the STS, while destroying – discontinuing – existing systems (Geels, 2002).

How discontinuous innovations break through the inertia of the existing STS is heuristically described by the so-called "multi-level perspective" (MLP) (Geels, 2002, 2018), see Figure 2-1. The MLP holds that radical innovations are nurtured in a "niche" (Kemp et al., 1998) that acts as "protective space" (A. Smith & Raven, 2012) against a STS' selection environment. A niche may be a technological experimentation niche or a market niche (M. Weber et al., 1999). At the variation stage, niches comprise various different yet associated innovations to resolve a certain local resource allocation disequilibrium, for instance slightly different technological solutions for the same problem. For instance: both battery and hydrogen electric vehicles are two options competing in the same niche. Over time, niches converge towards a best-fit solution to dissolve the disequilibrium, a process that was called "niche accumulation" (Geels, 2002; Raven, 2007). At this point, a "technology battle" between competing technological designs may take place (Suarez, 2004). The outcome of the niche accumulation is a "dominant design" (P. Anderson & Tushman, 1990), or: industry standard – the best-fit solution. Because a niche is not retained by society's STS yet, it requires continuous external investment to be maintained (Rip & Kemp, 1998). After a niche has successfully converged and passed through the selection stage, it may get integrated into society's STS, a process called "structuration" (Fuenfschilling & Truffer, 2014). As consequence, the STS "reconfigures" to accommodate the discontinuous innovation (Geels, 2002).

If a society changes from one dynamically stable STS to another, one speaks of a "transition" (Geels, 2002). Because a radical innovation needs to overcome a STS' inertia, one may speak of the whole process, from niche accumulation, over structuration to reconfiguration as "niche breakthrough" (Geels, 2007). A niche breakthrough may only be possible if broader societal trends, called "socio-technical landscape", create a window of opportunity for doing so (Geels, 2018; Geels et al., 2017). In other words: a niche can only breakthrough if the societal conditions, including perceived problems that should be solved, are matching the problem-solving activity of that niche. In addition to niche breakthrough, an existing STS may radically change for instance through a process called "punctuated equilibrium" (Levinthal, 1998) in which old technologies are applied to new applications, without the need to reconfigure the entire STS.

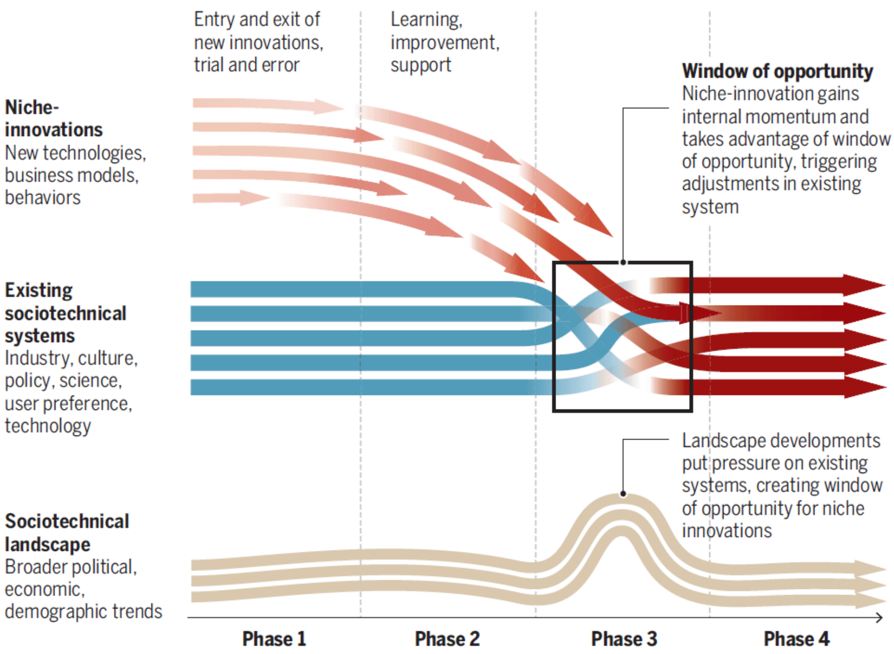

Figure 2-1: The Multi-Level Perspective Summarised.
(From Geels et al., 2017, p. 1244)

The evolutionary process describes thus far is, more precisely described, *co-evolutionary* (Dosi, 2013).[4] Hence, it involves positive feedback loops between all actors within an STS – there is mutual exertion of influence and interdependency. For instance: as indicated with technology push and market pull above, supply may create demand, or demand may create supply (Kemp et al., 1992; Leonard, 1988). Another example is the co-evolution between the variation stage and selection stage (J. W. Schot, 1992): anticipating the selection pressures by the selection environment, actors in a niche may adapt their behaviour before selection pressures even occur.

The conclusion of this chapter is that innovation is a complex process involving co-evolution between actors and the environment in which they are embedded. Understanding how the CM industry evolves therefore requires an analytical angle that can give justice to this complexity. The next section introduces such an analytical lens.

2.1.2. Innovation Systems

Who creates innovations? In early studies on innovation, they were seen as the product of certain individual's endeavour, for example Schumpeter's view of the innovator-entrepreneur (1934). However, one key advancement in the study of innovation was that it is the outcome of a *collective process* (Coenen & López, 2010; Dosi, 2013; Fagerberg, 2006). Consequently, the complex interactions that yield innovations were described as "innovation system" (IS) (Edquist, 2006, p. 1): "all (…) factors that influence the development, diffusion, and use of innovations".

The literature describes as the constituent components of an IS *actors*, *networks* between them, *institutions* governing them (Bergek, Jacobsson, Carlsson, et al., 2008; Benny Carlsson & Stankiewicz, 1991; Edquist, 2006; Hekkert et al., 2007), and *technology* (Bergek, Jacobsson, & Sandén, 2008). *Actors* refers to all actor groups that may exert influence on a given innovation (Bryson, 2004). *Networks*

[4] The co-evolutionary logic of innovation processes hints to the possible observation that the evolutionary theory of innovation, including the MLP framework, can be viewed as an application of complex adaptive systems theory to the case of innovation (Allen, 2014). Complex adaptive systems theory is a theory in complexity science that seeks to describe general properties of complex systems, using concepts such as emergence, self-similarity, non-linearity, and self-organisation (Dosi, 2013; Foster, 2005; Holland & Miller, 1991).

refers to social networks consisting of *strong ties* between individuals, for instance two people regularly interacting, and *weak ties*, for instance contacts that occur through an occasional meeting (Granovetter, 1983). *Institutions* refers to all *formal* and *informal* rules that govern social interactions. Particularly, institutions may be *regulative* (e.g. laws, standards, procedures), *normative* (e.g. values, norms), or *cognitive* (e.g. beliefs, search heuristics) (Geels, 2004). *Technology* refers to the technological system of the innovation under study, consisting of a focal technology and upstream *components* and downstream *complements* (Adner & Kapoor, 2010; Bergek et al., 2015; Wesche et al., 2019). The technological system is conceptually strongly overlapping with an industry's *value network* (Christensen & Rosenbloom, 1995).

For applying the IS framework, system boundaries need to be chosen – one cannot analyse *all* factors that influence the innovation process in their exhaustive entirety. Accordingly, different foci for understanding and analysing IS exist, each with a slightly adjusted epistemology. One can differentiate focused IS frameworks by geographical focus and by technological focus. In reality, however, all IS, be it scoped by geography or technology, interact and overlap (Hekkert et al., 2007).

With geographical focus, the literature typically differentiates between regional IS (Cooke et al., 1997) and national IS (Chris Freeman, 1995). The regional IS describes what is conventionally described as a 'innovative' or 'entrepreneurial' region, for instance the Silicon Valley in the USA. However, independent of such 'star regions', the framework also provides an account if more subtle differences between regions, for instance why certain regions have more active companies than others. The national IS seeks to do the same, merely on the scale of nations. Freeman (1995), for instance, described what enabled Germany's industrialisation catch-up in the late 19th and early 20th century. National IS consist of many regional IS, and accordingly the boundary between both frameworks is fluid (Chung, 2002).

With technological focus, the literature typically differentiates between technology-specific IS (Benny Carlsson & Stankiewicz, 1991) and sectoral IS (Malerba, 2002). A technology-specific IS is, as the name indicates, limited to a clearly delineated focal technology, for instance the IS involved in the creation of wind turbines. A sectoral IS puts a broader scope of interrelated technologies, for instance the IS for renewable energies. Again, a sectoral IS is merely a higher order scope than a technology-specific IS, so the boundary between both is fluid.

The conclusion of this chapter is that IS is a workable framework to describe the complexity of the innovation process. While the IS framework comprises different angles, that of a technology-specific innovation system appears most appropriate to the topic of this research. I subsequently discuss this framework in more detail.

2.1.3. Technology-Specific Innovation Systems

The description of IS provided in the last section focused on structural aspects of IS: actors, networks, institutions, and technology. If wanting to understand how an IS produces a certain innovation as an outcome, however, such a description may be too imprecise and static (Hekkert et al., 2007) and not systematic enough (Bergek, Jacobsson, Carlsson, et al., 2008). For instance: how exactly do actors create an innovation? To understand how an IS produce an innovation, looking at *functions* (or: activities, processes) occurring within an IS may provide answers.

For TIS, converging research indicated a set of about seven functions in a TIS that are relevant to the production, diffusion and use of the TIS' innovation (Bergek, Jacobsson, Carlsson, et al., 2008; Hekkert et al., 2007). The exact set of these functions differ by author, and in this work I use the set of seven functions as suggested by Bergek, Jacobsson, Carlsson, et al. (2008).[5] In comparison to the scheme by Bergek et al. (2008), Hekkert et al. (2007) differentiates function #1 into two functions: Knowledge Development and Knowledge Diffusion. However, recent research indicated that this differentiation may not be helpful (Planko et al., 2017; Wydra, 2019). In addition, the scheme by Bergek et al. incorporates the development of positive externalities as an additional function. Recent research also pointed out the importance of such factors for the development of a TIS (Bergek et al., 2015; van Welie et al., 2019; Wesche et al., 2019). Both points together explain why I chose the framework of Bergek et al. (2008) over that of Hekkert et al. (2007). The seven functions that are used in this work are summarised and described in Table 2-1.

Table 2-1: Summary of TIS Functions.
(Based on Bergek, Jacobsson, Carlsson, et al., 2008; Bergek, Jacobsson, & Sandén, 2008; M. P. Hekkert et al., 2007; Planko et al., 2017)

#	Function	Description
1	Knowledge Development and Diffusion	Functions and activities related to the creation and network-based diffusion of all types of innovation-relevant knowledge, specifically research and development (R&D) related scientific and technological knowledge. Entails 'learning by searching', 'learning by doing', 'learning by interacting', and 'learning by using'.
2	Entrepreneurial Activity	Entrepreneurs and start-ups are the driving force behind many innovations. In addition, corporate ventures may drive innovations.
3	Resource Mobilisation	Different types of resources exist, and the question arises whether they are applied to the TIS at hand. The types of resources discussed in the literature are typical financial capital (e.g. available investment) and human capital (e.g. graduates in a given field).
4	Positive Externalities	Positive externalities refer to positive effects for a company arising from network effects of the presence of other companies etc. In economics, the effect is explained by external economies of scale, i.e. that a company's cost function is reduced because of external factors. See also section 1.3 on positive externalities.
5	Legitimation	Power plays an important role in shaping socio-political functions around a TIS. Activities in this function are for instance the extend of lobbying activities for the focal innovation, the extend of support (or opposition) by civil society actors, and the reaction to the innovation by incumbent producers of substitute products.
6	Search Guidance	Resources are scarce and the question is whereto they are allocated. In this function, all activities are bundled define resource allocation. These are visions, expectations, priorities, and goals by stakeholders.
7	Market Formation	For many innovations, one of two scenarios tend to occur: either they cannot compete directly against existing technologies because their price/performance ratio is inadequate, or they can simply not be sold because the market infrastructure, for instance distribution channels, is underdeveloped. Activities in this function either provide protection against existing competition or develop the market infrastructure.

The functions can be used as a framework to evaluate a TIS. To do this, typically qualitative data is interpreted through the lens of the framework. Similar function-based analyses are widely used in social science research under the umbrella term of "process tracing" (Bennett & Checkel, 2015). The functions are operationalised for analysis in section 3.3 of the methodology.

The activities performed in the seven functions overlap and interact (Hekkert et al., 2007). For instance: entrepreneurs (function #1) may create high expectations for a certain technology (function #6), leading politicians to endorse the technology (function #5) and allocate public research funds for its development (function #3). If the mutual influence of functions yields a reinforcing, positive feedback loop, one may speak of a "cumulative causation" (Suurs & Hekkert, 2009) through "motors of change" (Hekkert et al., 2007). The opposite case, a negative feedback loop, is also possible. There is no guarantee that a TIS entails a positive feedback loop, and if there is none, the TIS may never evolve.

Over time, TIS go through lifecycle stages (Bergek, Jacobsson, Carlsson, et al., 2008; Markard, 2020). At the beginning, when the fate of a TIS is uncertain, it is in the *formation* stage. After positive feedback loops of the TIS' functions fuel its development, it is in a *growth* stage. Once this mutual reinforcement

[5] The order of the functions was changed to support comprehension.

stagnates or declines, a TIS is in a *maturity* stage. Latest when negative feedback loops occur, the TIS is in a stage of *decline*. Overall, the life cycle time of a TIS may differ substantially and is dependent on a technology's use in society. The lifecycle stage of the TIS analysed in this work is discussed in section 3.1.2 of the method.

Having described the framework used for this work, the next section discusses related frameworks.

2.1.4. Transition Frameworks

Three frameworks besides TIS are often used for related analyses: the already-introduced multi-level perspective (MLP), see section 2.1.1, strategic niche management, and transition management. In this section I shortly describe the three frameworks, and why I consider them unfit for the analysis I intend to conduct.

The MLP framework is mainly used by researchers to analyse macro-level changes between two states of society's STS, i.e. transitions. Most MLP analyses focus on "sustainability transitions" (Köhler et al., 2019), for instance a transition towards a more sustainable energy system (Geels, 2018; Geels et al., 2017; Strunz, 2014), or historical cases (Geels, 2005, 2007). For an MLP analysis, factors at the STS and landscape level are identified that interact with developments in niches, promoting or impeding the process of niche accumulation.

The MLP framework is deemed unsuitable as primary framework to analyse a focal industry because it is not focused on developments within a given niche. The MLP looks at the interaction of different phenomena at different complexity scales of society, and how these interactions produce a certain outcome. For example: MLP was used to explain how the development of electric vehicles was thrown back by World War I (Geels, 2005). Hence: a micro phenomenon (a technological niche, electric vehicles) is influenced by a macro phenomenon (a landscape event, World War I). Such analyses have merit of their own and could be applied to contextualise the development of the CM space in general. However, an MLP analysis would not allow a detailed look at the CM industry by region, and how it differs. Hence: an MLP analysis could complement a TIS analysis, but not substitute it. The time for this thesis was limited, and methodological decisions needed to be taken. Instead of doing a TIS-complementing MLP analysis, I decided to do an TIS-expanding thematic analysis, see section 3. Doing both analyses on top of the TIS analysis was deemed unrealistic given the time constraints. I discuss the potential to complement the analysis at hand with an MLP analysis in the discussion, section 7.2.

Another framework often used for similar analyses is strategic niche management (SNM) (Kemp et al., 1998; Raven et al., 2010; J. Schot & Geels, 2008). SNM is used to understand micro-level activities within a given niche. For instance: how are the expectations of actors within the alternative protein niche converging? The focus lays here on experimentations within a niche. Because of its micro-level focus, the SNM framework could be in principle interesting to answer the research questions asked in this work.

However, in practice the SNM is deemed not a good fit to answer the research question asked in this thesis for two reasons. Firstly, the SNM looks at the evolution of niches based on experimental learning; a scope likely not entirely relevant to answer the research questions of this thesis. These experiments are, for instance, tests and pilots with users. The learnings from these experiments are then feed-back to the niche and influence it, leading to an increasing alignment of the niche with its users (Leonard-Barton & Deschamps, 1988). However, the CM industry is still entirely research and development (R&D) driven (GFI, 2019a). In other words: there are almost no public tests and pilots occurring. And even if there are for example rare public tastings, they only happen to showcase the state of R&D, not to collect user feedback. A SNM analysis would then, for instance, illustrate how CM companies adapt their R&D strategy based on external feedback. However, overall key aspects of the production system of CM are known and do not vary between actors (GFI, 2018c), see also section 4.2. Hence, I expected that a TIS analysis, with its broad set of indicators to be analysed, would yield more relevant results to compare the CM industry cross-regionally than SNM. Even if CM companies incorporate external feedback to influence their R&D, these dynamics are likely less pronounced than those uncovered by a TIS analysis. Secondly, SNM was designed as a policy framework to provide prescriptions on how to nurture or govern niche developments. The framework entails guidelines for policy-makers on how to select experiments, set them up, and potentially scale them up (Caniels & Romijn, 2008; Porter et al., 2015). Given what is known about the CM industry prior to this research (GFI, 2019a; Stephens et al., 2018), I suppose it is reasonable to suggest that the direct influence of policy makers or governments on the CM space is very limited, if not non-existent. The approach suggested by SNM, to provide recommendations to policymakers to directly influence a niche, are therefore unfit to support the analysis of the CM industry intended in this work.

A last framework used for analysis is transition management (TM) (Loorbach, 2010; Rotmans et al., 2001; Voß et al., 2009). In comparison to the frameworks of TIS, MLP, and SNM, the TM framework focuses on the participatory governance of transitions. The approach seeks to bring diverse actors in a niche and the STS together at one table, coined “transition arena”, to develop transition pathways, mobilize actors towards them, and evaluate the progress (Loorbach, 2010).

The TM framework deemed unfit for the analysis at hand for similar reasons as why MLP and SNM were not chosen. Most importantly, TM is a prescriptive policy framework. It was designed to help so-called ‘transition managers’ to nurture promising niches, for instance under the authority of a government. Thinking of niche-nurturing is not the goal of this research.

This work focuses on a fairly narrow technology: CM. Accordingly, the TIS framework is deemed as the appropriate framework. If the work would focus on CM’s superset, cellular agriculture, the framework of sectoral IS would arguably be more appropriate. The next section introduces the background for meat alternatives in general.

2.2. Meat Alternatives

Meat alternatives (or: meat analogues, meat substitutes) are products that mimic conventional meat in sensory qualities (taste, texture, etc.) (Bhat & Fayaz, 2011; Chatham House, 2019). By this biomimicry approach meat alternatives can be distinguished from alternative proteins (or: sustainable proteins), which include also plant-based products that do not mimic meat, such as tofu or soy, and sometimes also include purely plant-based products, such as chickpeas or mushrooms (WEF, 2019a).

The following sections first establish the case for meat alternatives with a focus on their potential to mitigate climate change, while then discussing insect- and plant-based and cultured meat in detail. For all three meat alternatives, first an overview is provided, and the consumer acceptance and market trends discussed. Further, for insect-and plant-based meat the production technology is discussed. The reader finds a similar yet more detailed overview of CM’s production technology with the results in section 4.2. Lastly, this section contains an overview of the public discourse on CM, discussing ontological and ethical questions related to it.

2.2.1. The Case for Meat Alternatives

As mentioned in the Introduction, meat consumption accounts for approximately 10% of global annual greenhouse gas (GHG) emissions (FAO, 2017). The livestock sector as a whole, including milk, eggs, and non-edible outputs, such as horn, accounts for 14.5% of global annual GHG emissions (FAO, 2013). Hence, meat constitutes about 69% of all livestock related emissions (FAO, 2017), a figure that is matched approximately by other models as well (Springmann et al., 2018). The entire agricultural sector, which includes also non-animal products, accounts for approximately 23% of global annual GHG emissions (IPCC, 2019).

Meat has substantially higher GHG emissions per unit of protein than non-animal protein, see Figure 2-2. Non-animal proteins are those from plants, such as legumes, for instance chickpeas. The reason for this difference can be explained by animals' enteric fermentation – gases from digestion –, meat's low food conversion ratio (FCR)[6], and manure related emissions (FAO, 2013; Springmann et al., 2018). For the whole livestock sector, 44% of GHG emissions stem from enteric fermentation and 41% from feed alone (FAO, 2017). As can be seen in Figure 2-2, meat from ruminant animals, typically from cows (beef meat) and sheeps (lamb meat), have substantially higher GHG emissions than meat from non-ruminant animals, typically pork and poultry. Key reasons for this difference are that pork and poultry have a lower slaughter age, increasing the feed-to-product energy conversion rate, and produce less gases during digestion, reducing emissions from enteric fermentation. The emission ratio per unit of protein between ruminant and non-ruminant meats is approximately 6:1, i.e. per unit of protein ruminant meats are associated with approximately 6x times higher GHG emissions.

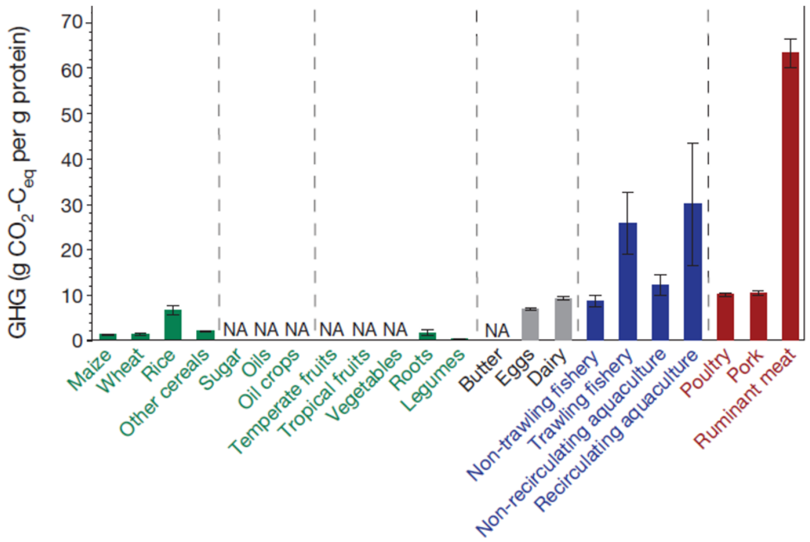

Figure 2-2: Greenhouse Gas Emissions[7] per Unit of Protein by Product.
(Adapted after Tilman & Clark (2014, p. 1); similar data in Clark & Tilman (2017) and Willett et al. (2019))

The high GHG emissions of meat is problematic not only because ongoing existing meat consumption, but because meat consumption is growing, see Figure 2-3. There appears to be a positive linear association between growth in GDP and meat consumption per capita (Sans & Combris, 2015). The richer countries become, the higher meat consumption is. After a certain point though, meat consumption per capita appears to stagnate and slowly decrease in high GDP countries (Cole & McCoskey, 2013; Vranken et al., 2014). Hence, the increase in total meat consumption is driven by developing countries. Worldwide population is expected to grow up to between 9 and 12 billion until 2100 (Gerland et al., 2014), mainly in developing countries. Also until 2100, GDP per capita is expected to grow in most scenarios between 4x and 10x times until 2100 (Cuaresma, 2017). As consequence of both trends, global meat consumption is expected to grow until 2050 by approximately 76% (FAO, 2012). The associated GHG emissions are expected to grow roughly proportionally (Springmann et al., 2018), assuming no substantial alteration of meat's emission profile.

[6] The food conversion rate is the ratio of feed required for the final product. If 2 kilograms of feed are required to 1 kilogram of final product, this ratio is 2:1. The food conversion ratio is thus a measure of the feed-to-product energy conversion.

[7] Measured in CO_2-C_{eq}, hence carbon dioxide equivalents. The unit allows to compare the effect of different greenhouse gases in one unit of measurement.

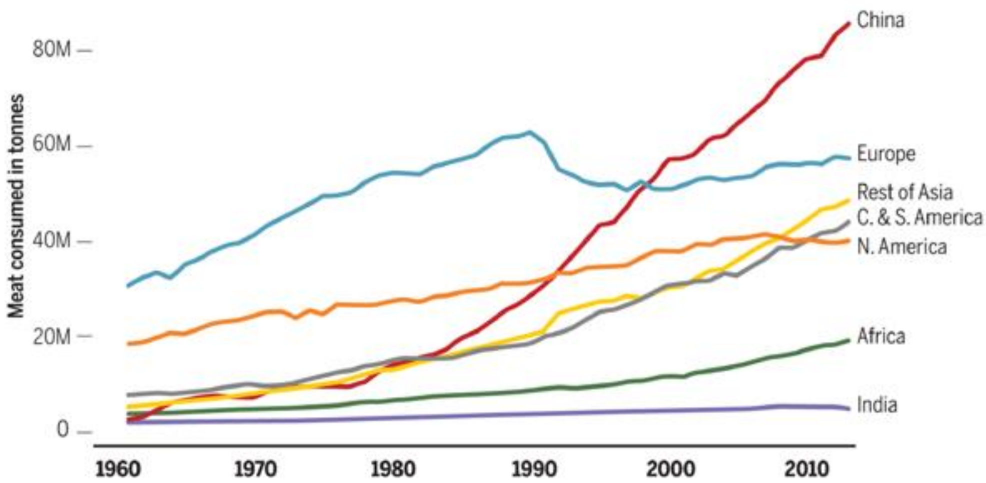

Figure 2-3: Growing Worldwide Meat Consumption.
(Adapted after Godfray et al., 2018, p. 1)

Meat alternatives promise lower GHG emissions per unit of protein, see Figure 2-4. As the reader can see in the figure, the emissions of meat alternatives are estimated to be approximately in the order of magnitude of meat from non-ruminant meats. Assuming equivalence in emissions between meat alternatives and meat from non-ruminant meats, this would mean that a substitution of ruminant meats by meat alternatives could reduce the respective emissions by a factor of 6. Of all meat related emissions, 73% stem from ruminant animals (cows, buffaloes, sheep, goats) (FAO, 2017), or 7% of global annual GHG emissions. Thus, the potential of meat alternatives is, assuming 100% diffusion, to reduce the 7% of the annual global GHG emissions by a factor of 6.

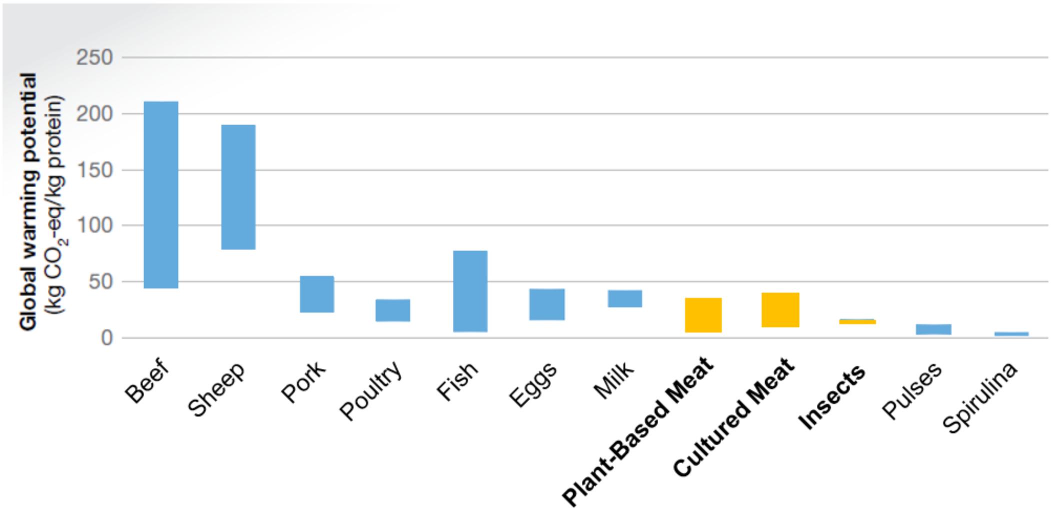

Figure 2-4: Greenhouse Gas Emissions[8] per Unit of Protein of Meat Alternatives.
(Adapted after Tuomisto, 2018, p. 4)

As the above data indicates, meat alternatives offer the potential to substantially reduce GHG emissions compared to conventional meat. A critic might note that this is also true for regular alternative proteins such as soy and for plain plants, such as chickpeas. Indeed: from a pure emission standpoint these alternatives may even be superior to meat alternatives. However, the problem arises whether consumers actually substitute meat by plant-based products. The demand for alternative

[8] Measured in CO_2-C_{eq}, hence carbon dioxide equivalents. The unit allows to compare the effect of different greenhouse gases in one unit of measurement.

proteins is clearly growing in developed countries (Winnie Gerbens-Leenes, 2017). Nonetheless, what remains are (a) developing countries, in which demand for meat is strongly growing, see Figure 2-3, (b) convinced meat eaters. Hence, although alternative proteins and meat alternatives are both needed, they likely address different segments of the population and thereby complement each other as solutions.

2.2.2. Insect-Based Meat

Overview

Insect-based meat is a meat-mimicking product made from processed insects. Consumption of insects dates back approximately 5.000 years (Bessa et al., 2017) and over 1900 different species are part of traditional diets of over 2 billion people worldwide (FAO, 2013). Modern Western usage of insects begun in the 1940s as fish baits, expanded in the 1970s to pet feed, and moved in the late 2010s to food for human consumption (Dossey et al., 2016). The insects most commonly eaten by humans are beetles, caterpillars, bees, wasps, ants, grasshoppers, and crickets (FAO, 2013), among others. In the context of human consumption, the focus laid in the West initially to sell insects as a whole, just as insects are consumed in traditional diets. However, consumer acceptance of insects in their whole form is limited in the West (Bessa et al., 2017). Consequently, founders started exploring using insects as food ingredient to relatable food products that could mimic conventional meat products, such as burger patties. As of 2019, there are approximately 280 insect companies active worldwide (Engström, 2019a), of which only a small fraction is focused on insect-based meat products.

Consumer Acceptance

Studies on the consumer acceptance of insect-based products yield mixed results, although the existing data dose not draw an exhaustive picture. If given the choice against conventional meat, only approximately 5% would pick insect-based meat (Hartmann & Siegrist, 2017a). Yet, if asking for willingness to try, the picture is a different one. In Belgium and Germany, approximately 20% of the population would be willing to consume insect-based meat as meat alternative (Hartmann & Siegrist, 2017b). However, if the sample is not drawn from the general population, but from a more innovative subset – people attaining a science night – the willingness to try increases up to 75% in one study (Rumpold & Langen, 2019). Likewise, it was surveyed in the US that 75% of customers would try insect-based products (Tao & Li, 2018). Studies applying statistical regression indicate that positive predictors for a higher willingness to consume insect based products is being male and health-conscious (Orsi et al., 2019; Wilkinson et al., 2018). Also, maybe unsurprisingly, those people exhibit food neophobia or higher disgust sensitivity are less likely willing to try insects (Orsi et al., 2019). Food neophobia is the fear of eating novel foods and people who rate high on a food neophobia scale tend to dislike novel foods in general (Damsbo-Svendsen et al., 2017; Pliner & Hobden, 1992). Disgust sensitivity is linked to food neophobia. Finally, participants in the West tend to be more willing to try insect in a processed form than as a whole, which speaks for insect-based meat as a product type (Hartmann & Siegrist, 2017b; Tao & Li, 2018). The reasoning behind this is that disgust is less triggered. Overall, it appears that insect-based products for human consumption are mixed received by consumers.

Market Trends

Overall, the worldwide market for insects for human consumption is strongly increasing. Between 2018 and 2023, the total worldwide market size is expected to nearly triple from $407million to $1.182million (Business Wire, 2018), which equals a compound annual growth rate (CAGR) of almost 20%. In North America and Europe, a CAGR of even 28% and 26%, respectively, is expected (Mekko Graphics, 2018). However, even in 2023 Asia-Pacific will probably remain the largest regional market for edible insects, with $477million almost twice the market size compared to the next two largest markets, Latin America and Europe (de Sousa et al., 2018).

However, all these figures refer to *all* edible insects, including its use in for instance snacks and protein bars. At the point of writing, existing forecasts did not include figures on insect-based meat as product category (e.g. Statista, 2018). When US consumers were asked in which product they preferred insects, 83% preferred it in other product forms than as main entree in a hidden form (as used for insect-based meat), for instance as snack or appetizer (Tao & Li, 2018). Overall, these statistics indicate that edible insects will grow generally as a market segment. But whether insect-based meat will become a big market remains to be seen. Arguably a broad acceptance on mass market scale cannot be expected, yet surely the development of niche markets.

Production Technology

Insect farming conceptually mirrors conventional animal farming practice, and is also called "mini-livestock" (Bessa et al., 2017). Insect farms have buildings that follow the structure of animal farming buildings: areas to prepare feedstock, a rearing area, processing areas and warehouses (Ortiz et al., 2016). The used feedstock and rearing process differs by insect species, again comparable to animal farming. For instance: while crickets and mealworms are reared in trays or boxes containing nutrients, for instance as substrates, houseflies and other flying insects are reared in sealed chambers. Figure 2-5 shows an example of a basic cricket rearing unit.

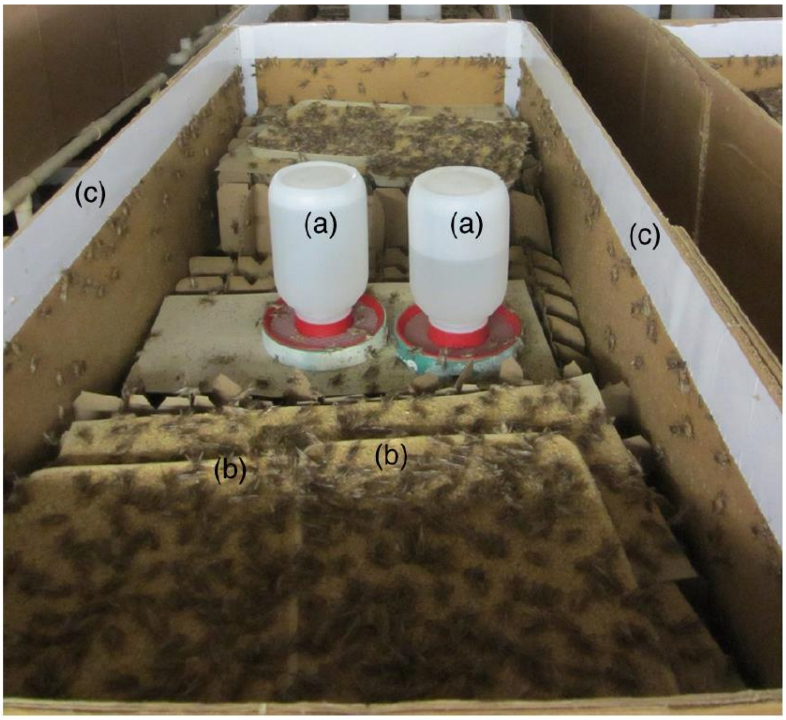

Figure 2-5: Example of a Cricket Rearing Unit.
(a) Watering units, (b) feeding trays, (c) smooth tape as escape prevention.
(Adapted after Ortiz et al., 2016, p. 180)

After the insects are reared, they are further processed. Firstly, the insects get cleaned from any feed residues. Then, they are killed, typically via shock freezing (Shockley & Dossey, 2014). Shock freezing is regarded as the appropriate killing method because insects are poikilothermic – 'cold-blooded' – i.e. they do not use energy to regulate body temperature (Bessa et al., 2017). Most insect's life naturally ends during winter. The freezing process thereby mirrors insect's natural end of life. After killing, the insects undergo a bacterial killing step. In conventional animal slaughtering, the digestive tract and its content are removed. Insects, however, are typically processed as a whole (Shockley & Dossey, 2014), including bacteria and other microbes contained in the digestive tract. For this reason, microbial "kill-steps", such as pasteurization, are required to make insects fit for consumption (Dossey et al., 2016). Finally, the insects are sold as a whole or further processed, the latter being the conventional step in the West. Intermediate products are mostly insect powders or pastes (FAO, 2013). From these intermediate products, the final feed or food products are made (Dossey et al., 2016). State 2019, there is a wide array of final insect-based products available, such as bars, cookies, crackers, noodles, oil, and, relevant to this thesis, burger patties and minced meat (Engström, 2019b).

Insect-based meat is produced by further processing insects as ingredient. To the best of my knowledge, no research exists documenting how these products are produced. However, the ingredient list of available products, e.g. the burgers by BugFoundation (2019) or Bold Foods (2019), two German insect-based meat start-ups, give some indications. Akin to conventional food processing, the insect proteins are mixed with other ingredients, for instance vegetables, soy protein, egg, oil, spices, etc., to create a product that should be comparable a conventional meat burger in sensory qualities. The production processes to create insect-based meat resemble that of plant-based meat, see below.

Until very recently, insect farming and processing was relatively little developed. Even in 2016, very limited research on advanced production processes for insects existed, and the degree of production mechanisation and automation was very low (Ortiz et al., 2016). In other words: most insect farms involved manual labour to a substantial degree. However, entrepreneurship in the insect space is growing exponentially (Dossey et al., 2016) as do patent applications (Kim et al., 2019), and more recent insect farming start-ups focus on advanced production processes that include robotic automatization (Mawad, 2019; Poor, 2019; E. Watson, 2019).

2.2.3. Plant-Based Meat

Overview

Plant-based meat (PBM) is a meat-mimicking product made from plant ingredients. Meat mimicry means that products are comparable or similar to conventional meat in sensory qualities (taste, texture, etc.). Plant-based meat can be differentiated from plant-based meat substitutes, such as falafel or tempeh, and naturally plant-based products, for instance chickpeas (GFI, 2019e). The earliest PBM substitutes for human consumption were developed as early as 1896 (W. Braun, 2017) and evolved considerably in the 1970s and 1980s (GFI, 2019e). Recently a new generation of PBM was developed, exemplified by the Beyond Burger or Impossible Burger, that have an unprecedented degree of meat mimicry compared to earlier products (Chatham House, 2019), such as conventional 'veggie burgers'. This new advanced PBM caters also to meat-reducing omnivores (flexitarians) (GFI, 2019e), a target market typically not addressed by PBM alternatives before.

Consumer Acceptance

In comparison to insect-based and cultured meat, the principal willingness to even try PBM is not a major issue (Hartmann & Siegrist, 2017a). In a hypothetical online choice experiment, plant-based burgers were chosen 27% of the time when they were available, compared to 69% for conventional meat (Slade, 2018). Hence: a high consumer acceptance can be expected, albeit conventional meat still has a higher acceptance.

Why nonetheless PBM is not favoured by all is explained by a variety of factors. Firstly, people high on food neophobia are also less likely wanting to eat PBM (Hoek et al., 2011). It's important to note that this rejection has not exactly something to do with PBM as such: people high on food neophobia tend to reject *all* novel food products more likely. Yet, this effect explains why still some people would not eat PBM. Secondly, meat attachment (Graça et al., 2015). Meat attachment refers to the fact that many people have a certain degree of attachment to meat. In other words: even if they were offered a PBM identical in sensory qualities, they would tend to prefer conventional meat. The reasons for this attachment are diverse, but one example is social identity. Eating meat in the West tends to be associated with masculine identity (Chan & Zlatevska, 2019). Giving up meat can thus be equated with loosing masculinity – and therefore people stay attached to meat.

Independent of these more complex psychological explanations, also more trivial reasons play a role. For instance, many consumers prefer conventional meat because its cheaper price and perceived-to-be-better in taste (The Grocer, 2018). And in fact, early PBM products received worse taste ratings in blind tasting than conventional meat (Schouteten et al., 2016). Likely, such ratings would look different if conducted with advanced PBM products, such as the Impossible Burger.

The real-life consumer acceptance of advanced plant-based products draws a clear picture. Products of the two most important producers at the point of writing, Beyond Meat and Impossible Foods, are extremely successful in the market. Between January and June 2019, Impossible Foods observed a 50% increase in revenue and faced issues keeping the supply up with the demand (Capritto, 2019). Beyond Meat's revenue grew between 2017 and 2018 by 170% and their products were often sold-out, too (Woods, 2019). If the product's price will further increase and the taste improve, we may observe a mass market for PBM in the near future (The Economist, 2019).

Market Trends
As to be expected from these aforementioned revenue figures, the worldwide market for PBMs is expected to grow strongly. Between 2018 and 2023, the total worldwide market size is expected to double from $10billion to $20billion (Statista, 2019b), which equals a CAGR of about 12%. This is 8 percentage-points below that for insects, albeit the forecast included *all* insect-based products, not only insect-based meat. In contrast to insects, the highest growth for PBM is expected in the Asia-Pacific region (GlobeNewswire, 2019), not in Western countries. Nonetheless, North America is and will remain the largest market for PBM worldwide, with an expected worldwide market share of about 44% in 2025 (Europe: 39%) (Statista, 2019a). In summary, a high growth for PBM is to be expected.

Production Technology
The production of PBM is conceptually not much different to the processing of conventional food ingredients to a final product. The processing steps undertaken on these inputs are for instance "milling, pounding, soaking, extruding, applying enzymes, etc" (GFI, 2018d). Extrusion – the usage of pressure for the processing of inputs –, for instance, is similarly used to produce diverse conventional food products, such as pasta and cereals (GFI, 2019d). Overall, the production process of advanced PBM appears not much different from earlier generation PBMs.

However, two innovations constituted the recent advancement in PBMs. The first was rethinking how PBMs are made. Instead of using available raw materials to produce PBM products, one begun to reverse engineer the final product and sought to understand which raw materials could yield the sensory qualities one wanted (GFI, 2018d). Through analytical tools such as trait mapping crops were identified whose taste profile could resemble meat more closely. Secondly, some companies begun to complement naturally occurring ingredients by genetically engineered ones (GFI, 2019e). Particularly the firm Impossible Foods uses genetically-modified legume haemoglobin, a protein that carries heme. Heme, on the other hand, is a molecule that carries iron. Through using plant-based heme in the Impossible Burger leaves the iron-y flavour as animal-derived meat has.

2.2.4. Cultivated Meat
Because CM was already broadly explained in the Introduction, I describe directly details in relation to it in this section.

Consumer Acceptance
The consumer acceptance of CM was seen as a critical issue for CM (Stephens et al., 2018), considering the consumer resistance against past food innovations such as GMOs (Mohorčich & Reese, 2019). The consumer acceptance of CM appears to differ quite strongly by surveyed country (Bryant & Barnett, 2018). In most Western countries approximately 50-75% of consumers are expected to be willing to eat CM (Bryant & Barnett, 2018; Mancini & Antonioli, 2019; Post, 2014; Surveygoo, 2018). In China and India, the only two non-Western countries for which data is available, approximately 90% of the surveyed sample would be willing to eat CM (Bryant et al., 2019). Overall, it appears that a broad consumer acceptance of CM can be expected, despite some regional variations. Nonetheless, the consumer acceptance will probably be, at least early on, more limited as for PBM. In the same hypothetical online choice experiment cited earlier, 13% of consumers would purchase CM when it would be available, compared to the 27% for PBM and 69% for conventional meat (Slade, 2018).

One should note, however, that this consumer acceptance is neither set in stone nor unchangeable. What will be the *real* consumer acceptance of CM, and the other meat alternatives discussed in this section, remains to be seen. The surveys here only give an indication and their external validity (generalisability and applicability to the real world) remains to be seen. Likewise, things change. Although for instance insects are not commonly eaten in Western countries, they are commonly eaten in other areas, indicating the role culture, particularly social norms, plays in shaping the acceptance of foods (Tan et al., 2015). In fact, social norms are known to be a key determinant in consumer behaviour of food (A. R. H. Fischer & Reinders, 2016) and social norms can change, although it may take decades (e.g. Nyborg & Rege, 2003). Thus, how CM and the other meat alternatives are accepted by consumers and how it will change over time cannot be determined beforehand.

Market Trends
CM is not yet available in the market, so all estimates for market trends should be taken with a pinch of salt. However, as with the other meat alternatives, the CM market size is expected to grow steadily over the next decades once it is available in the market. As mentioned, the management consultancy firm A.T. Kearney estimated that CM would constitute until 2040 up to 35% of the global meat market at a total market size of $630 billion (2019). They estimated a CAGR of 41% between 2025 and 2040 (A.T. Kearney, 2019). Other existing forecast make different assumptions and expect for instance the total market size of CM to $593 *million* until 2032, at a CAGR of about 16% between 2025 and 2032 (MarketsandMarkets, 2019). Another forecast predicts a total CM market size of merely $19 million by 2026 with a CAGR of 4.4% (Reports and Data, 2019). Although the total market size predictions have different base and end years and are thus difficult to compare, the varying CAGR figures indicate how strongly the forecasts differ in reality. In absence of real market data, these forecasts rely on quantitative forecasting with an extremely high degree of uncertainty, or even, as in the case of A.T. Kearney, on "qualitative forecasting" (A.T. Kearney, 2019, p. 16). Overall, no reliable market trends for CM can be indicated. However, if CM is successfully introduced to the market, all analysts are expecting a growing market size and thus the success of the product.

Public Discourse
CM raises philosophical questions, particularly ontological and ethical in nature, that are of relevance in the public discourse.

Ontologically, the problem arises what CM actually *is*. CM is not exactly the same thing as conventional meat: it does not come from a living animal. However, it is also living tissue. As Stephens (2010, p. 399) wrote: "'So is in vitro meat really the living-dead, the dead-living, or the living-never born'?". One may argue that this ontological issue arises from human cognition. One key process that allows humans to make sense of sensory information and reasoning in general is categorisation (Hayes et al., 2014). In other words: people simplify reality by putting things into comprehensible boxes. Human categorisations of reality are not random, but created following the logic of evolutionary-evolved cognitive modules (Sloman et al., 2007). In our ancestral past, domain specific modules evolved (Hirschfeld & Gelman, 1994), for instance a module for face recognition (Kanwisher, 2000), whose functions contributed probabilistically positively to our species' survival. The categorisations derived from these domain-specific modules are thus teleological, i.e. goal-oriented or inhibiting a specific purpose. Human cognitive categorisation, based on teleological simplification, is an answer to what artificial intelligence researchers call "frame problem" (Dennett, 2006): reality can be interpreted in an indefinite number of ways, without assuming 'components' of that reality as stable – the frame –, which is done by human categorisation. In addition, the categorisations derived from these modules tend to be essentialistic, a circumstance summarised as "psychological essentialism" (Haslam, 2014; Vosniadou & Ortony, 1989). Intuitively, we reason that categories are homogenous, i.e. clearly separable from other categories, and that they inhibit an 'essence' that constitutes them as a category. For instance: we may think intuitively of cows as a homogenous species and certain properties make these cows, cows, such as eating grass, give birth to calves, and so on. How human cognition operates, particularly categorisation, makes CM a difficult case. An 'essence' for CM has not yet developed in our collective consciousness. And as long as this is not the case, CM will necessarily cause problems because people lack, literally, the means of comprehending it as a category. Instead of understanding CM as its own category, people may tend to associate it with other, more broader categories, which brings me to ethical concerns regarding CM.

Ethically, CM is often associated with broader concerns regarding biotechnology (Dabrock, 2009) that may be summarised with a question: 'are we playing god?'. In the past, humans were bound to at most channel the direction of 'natural' evolution, for instance through animal domestication (Diamond, 2002) and the domestication of ourselves as species (Henrich & McElreath, 2007; Leach et al., 2003). Creating entirely new pathways for evolution, as potentially possible through biotechnology, particularly synthetic biology, was not an option (Luisi, 2016). These new possibilities raise fundamental ethical questions. For instance: if we can create new life, maybe even more intelligent life, what is the meaning of human existence (van den Belt, 2009)? In practical terms, such questions may have evoked, probably not mono-causally, but at least partially, public resistance against novel technologies (Bauer, 2015). A prominent example is the public resistance in Europe against GMOs (Lucht, 2015; Scholderer, 2005). This resistance exists despite that GMOs tend to be considered safe if properly used (de Vos & Swanenburg, 2018; Domingo, 2016) and have a positive impact on sustainability-relevant factors such as crop yield and farmer's income (K. Fischer et al., 2015; Raman, 2017). Some observers raise concerns that CM will face similar public resistance as did GMOs (Bryant & Barnett, 2018; Mohorčich & Reese, 2019; Stephens et al., 2018). Overall, ethical concerns regarding CM exist, and they may be related to broader ethical concerns in relation to biotechnology. What exact role these concerns will play, whether public resistance against CM will evolve, and how CM will eventually be categorised, remains to be seen. Answers to these questions remain speculative until CM is introduced in the market.

2.3. Section Conclusion

In this section, I provided the background to the theoretical framework that is used and on meat alternatives, of which CM is one.

In terms of theoretical framework, the TIS framework is used (Bergek, Jacobsson, Carlsson, et al., 2008; Hekkert et al., 2007). The framework is deemed appropriate for answering the research questions of this work because it offers fruitful analytical lens to do so, as highlighted by the fact that the framework is often used for similar purposes (e.g. Decourt, 2019; Wesche et al., 2019; Wydra, 2019).

The TIS framework is chosen over other alternative frameworks, particularly over MLP and SNM, because its analytical scope matches better the questions asked in this work. While MLP is too macroscopic, SNM is more suited an analysis of a niche prior to convergence, a point the CM industry has arguably already surpassed.

For meat alternatives, two other product groups where evaluated besides CM: insect-based meat and PBM. For all three the (prospective) consumer acceptance and market trends were described. Overall, it appears that the strongest competitor to CM will be PBM. In a 2019 report, three reasons were given why insect-based meat is likely not a big contender to CM (GFI, 2019b). Firstly, insects have a lower *food conversion rate* than plants, limiting the theoretical emission reduction potential for them compared to PBMs. Secondly, insect farms inherently pose a threat to local ecosystems because of the possibility that insects escape during a natural disaster, the report argues. If insects escape, it would be unfeasible to capture them again. Thirdly, insects require apparently for human consumption a consistent diet of grains, fruits, and vegetables. If insects are fed waste products and other cheap inputs, their taste is too inconsistent for human consumption. Because of these feed requirements, insects could only be cheaper than conventional meat if they are used as feed, not as human food. And if used as feed, they still align with the conventional meat supply chain. Whether or not one agrees with the details of this report, one may conclude: the role of insect farming, and insect-based meat particularly, is arguably not very strong compared to PBM, whose consumer acceptance is expected to be substantially higher. In conclusion, we may infer that we may see a technology battle (Suarez, 2004) between PBM and CM, a theme to which I return in the discussion in section 7.1.2.

Having provided this thesis’ background, the next section elaborates on its methodology.

3. Methodology

This section describes the methodology of this work. To answer the research questions, a case study approach is chosen. Data was collected via desk-research and interviews. For analysis, the TIS framework, introduced in the Background, is used. The framework is operationalised for analysis in this section, too.

3.1. Case Study Approach

3.1.1. Overview

The method applied in this work is a comparative case study analysis. A case study analysis is the analysis of a contemporary phenomenon within its context aimed at understanding “how” and “why” questions (Yin, 2014). The comparative approach is “considered the only choice for controlling hypotheses that apply to large units that are too few for statistical analysis” (Della Porta & Keating, 2008, p. 202). By relating two or more cases of the same phenomenon to each other, the comparative method allows to control for confounding variables and analyse the influence of the independent variables (Moses & Knutsen, 2012). The IS framework can only be supported partially by quantitative data (Hekkert et al., 2007; Zolfagharian et al., 2019), and accordingly the usage of the comparative case study method appears appropriate.

3.1.2. Case Demarcation

For conducting a case study the case under study needs to be demarcated (Yin, 2014). In this work, an IS is analysed, following the TIS framework introduced in the Background. Thus, the IS under study needs to be demarcated for this work (following also Bergek, Jacobsson, Carlsson, et al., 2008). Below I first characterise the innovation system again for clarity, and then define its boundary.

Innovation System Characterisation

As described in section 1.3, the CM industry is in this work understood in this work as IS. For this reason, the CM industry is not only understood as all focal actors active in CM; it entails all actors, networks, institutions and technologies in relation to it in the defined geographies.

Linking to the lifecycle stages of an IS (Markard, 2020), the CM IS can be characterised to be still in the earliest phase of *formation*: no CM product is sold state 2019 (GFI, 2019a), and which CM technology exactly will lead to market introduction is still an open question (Stephens et al., 2018).

Innovation System Boundary

The TIS system boundary is set geographically to the USA and in Europe. The region “Europe” requires further scoping: studying all 32 countries of the European Union (EU) and the four additional countries of the European Free Trade Association appeared unrealistic. Therefore, I decided to focus in Europe on the Netherlands, Germany, France, and the United Kingdom. These specific four European countries were chosen after applying three criteria: CM-related activity, economic significance, and start-up activity. Regarding CM-related activity, the Netherlands is the only European country that hosts CM companies that received funding at the time of writing (GFI, 2019a) and was therefore included. In terms of economic significance, Germany, France and the United Kingdom are the three largest economies of Europe (Eurostat, 2019) and were therefore included. Regarding start-up activity, the four already selected countries were also those with the highest number of start-up companies in Europe (MWCapital, 2019), confirming the country selection. Conducting the analysis across national borders is consistent with the TIS framework (Bergek et al., 2015; Hekkert et al., 2007), which assumes that TIS often span national borders. At the time of writing there was free movement of goods and people between these four countries, making a TIS spanning several countries appear realistic. In summary, the geographical scope means that the TIS for CM in the USA is conceptualised to end at the national border, while the TIS for CM in Europe is conceptualised to span the Netherlands, Germany, France, and the United Kingdom. Where relevant, I may consider linkages to other countries, too.

3.2. Data Collection

3.2.1. Data Sources and Descriptive Information

Data for this work was collected from two sources: desk-research and expert interviews. The desk-research was focused on collecting quantitative data and background information. I sought to derive as much objective information possible to answer the research questions at hand. For the desk-research, I relied mostly on secondary data such as peer-reviewed publications and reports from NGOs.

Set against the stage provided by the desk-research, I conducted expert interviews to qualify and complement the results. When the quantitative data from the desk-research indicated a clear interpretation, the main goal was to understand *why* the data shows that picture. Where there was no or limited quantitative data available from desk-research, the interviews were more explorative in nature. The interviews were recorded either via the online meeting software "Zoom"[9] or via a physical recording device, if conducted in person. Zoom records audio and video, leading potentially to even higher data quality than in-person recording. Online interviews were only conducted if a stable and strong Internet connection was available on both sides.

The interviews were conducted as follows. The data was collected between August and December 2019. A total of 21 interviews were held, of which 13 were mainly (but not exclusively) relevant to Europe, and 8 to the USA. The interviewees were recruited through personal contacts from the *Good Food Conference 2019* in San Francisco, USA, and the *5th International Scientific Conference on Cultured Meat 2019* Maastricht, Netherlands. All interviews but one were conducted via Zoom, leading to a high average recording quality. The interviewees belonged to a diverse set of actor groups, see Table 3-1. Hence, although the selection was based on a convenience sample, I believe the sample is not biased in an obvious way. While 7 interviewees were conducted with individuals that could be described as 'comprehensive' experts in CM (for instance an investor in CM with strong knowledge of the space), the remaining 14 interviewees were individuals with more specialist, narrow expertise of CM (for instance an employee of a big pharmaceutical firm that evaluated CM's impact on incumbent companies). The interviews with the comprehensive experts typically covered a wide range of topics, while the interviews with the specialists were typically focused more narrowly. In other words: some interviews covered several TIS functions, see Table 2-1, while others focused only on one or two. As recommended (Edwards & Holland, 2013), I followed a topic guide to semi-structure the interviews. All interviews were conducted to span an arc from the general to the specific. I started always asking about the general state of the industry, and then dove into more detailed questions regarding specific TIS functions in which the interviewee appeared knowledgeable. More details on the interview procedure and the entire topic guide is found in Appendix A. The interviews had an average duration of 40 minutes with a standard deviation of 13 minutes; the shortest interview was 22 minutes, the longest 69 minutes.

Table 3-1: Number of Interviews by Actor Group.

Actor Group	Number of Interviews
Entrepreneurs, Ventures and Suppliers	4
Scientists and Researchers	4
NGOs and Support Groups	4
Government, Regulatory Bodies and Related	3

[9] Available online at: https://zoom.us/; accessed 12/12/2019.

Incumbent Companies	2
Investors	2
Journalist	2
Total	**21**

3.2.2. Ethics

The data collected complied with the human research ethics guideline of TU Delft.[10] Interviewees were asked for their informed consent, which was revocable. No personal data of the interviewees was stored, besides those specifically relevant to this research. The interview data was stored in an encrypted hard drive.

3.3. Data Analysis

The analysing the data that was collected, the I followed the subsequent process.

Firstly, all recorded interviews were transcribed. Conventionally, verbatim transcription is recommended for transcription of qualitative data (Oliver et al., 2005; Poland, 1995). For 'true' verbatim (or: naturalised approach) every single sound including nonverbal sounds (e.g. laughs) are noted, while for 'intelligent' verbatim (or: denaturalised approach) only the content and sentence structure is maintained (Bucholtz, 2000). While verbatim is the ideal form of transcription, in practice, however, the researcher should pick the level of detail for the transcription required to answer the research question at hand (Davidson, 2009). The research questions of this work required exclusively 'information extraction' from the interviews, contextual information (e.g. laughs) or social cues (e.g. hesitation) played no role whatsoever. Instead, efficient processing of the interviews played a more important role than perfect accuracy of the wording. Hence, for transcribing the interviews, an automated software that uses speech-to-text technology was used.[11] While manual verbatim transcription has typically about 99% accuracy in speech-to-text, automated speech-to-text technology typically reaches about 90-95% (DeMuro & Turner, 2019). While the usage speech-to-text technology may not be considered appropriate in all contexts, if information extraction is the only goal, it tends to be considered appropriate (Alcock & Iphofen, 2007; Moore, 2015). If the transcription appeared insufficient to code accurately the content, I went back to the recording, listened to it, and afterwards coded the content. Such a mixed approach, using speed-to-text technology and going back to the recording, is considered for certain contexts more efficient and effective (Halcomb & Davidson, 2006; Loubere, 2017; Tessier, 2012). Given the time and budget constraints of this thesis, yet the high number of interviews I conducted, I consider this case such a context.

After transcription, the interview content was coded. The software "Nvivo 10" was used for this purpose.[12] For analysing data, such as interview, one can either take a deductive (theory-led, top-down) or by inductive (observation-based, bottom-up) approach (Reichertz, 2013). Deduction is used to validate or falsify existing hypotheses, or to analyse a case through certain theoretical lens. Induction tends to be used to develop new hypotheses based on observations. Mixed approaches between deduction and induction, to strongly simplify, are called abduction (Magnani, 2005). Abduction is particularly used for theory building, by which induction informs a (preliminary) theory, which is then tested via deduction (Shepherd & Suddaby, 2017). For interview coding, this means that the content is either approach through a pre-defined structure (deduction), or through an open-ended thematic analysis (induction).

[10] Available online at: http://www.hrec.tudelft.nl/; accessed 14/12/2019.
[11] The service was Gong, accessible at: www.gong.io; accessed 14/12/2019. I had access to this service, although it is typically not used for academic research purposes. Yet, the speech-to-text technology is identical to other more commonly known services.
[12] Available online at: https://www.qsrinternational.com/nvivo/nvivo-products; accessed 14/12/2019.

The interview data in this thesis are analysed partially by deduction, partially by induction. For answering research questions 1 and 2, deduction is used. Particularly the TIS framework is used to analyse the data. For deploying these analyses the TIS framework needs to be operationalised (Bergek, Jacobsson, Carlsson, et al., 2008; Hekkert et al., 2007) – made measurable through indicators – which is done below.

For answering research question 3, induction is used. Particularly thematic analysis (Guest et al., 2011; Terry et al., 2017) is used to code the interview data. The thematic analysis will entail all themes that arise that do not fit in the TIS framework. It therefore summarised the 'residual' data from the interviews. The venn diagram in in Figure 3-1 illustrated the complementary role of the thematic analysis in relation to the TIS analysis.

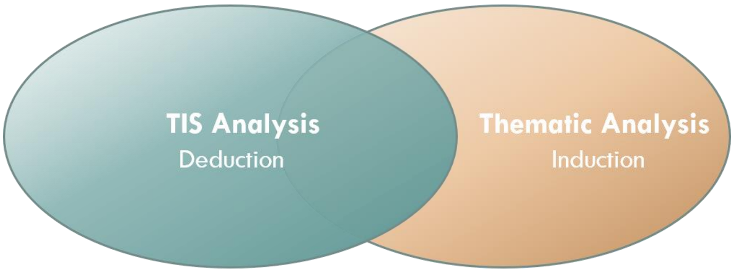

Figure 3-1: Complementary Role of TIS Analysis and Thematic Analysis.

The next three sections describe in detail the three analyses used in this thesis: the TIS analysis, consisting of structural analysis and functional analysis (Bergek, Jacobsson, Carlsson, et al., 2008; Hekkert et al., 2011), and the thematic analysis.

3.3.1. Structural Analysis

As introduced in section 2.1.2., the structural analysis entails the analysis of three components of the TIS: *technology*, *actors* and *networks* between them, and *institutions* governing them. Firstly, technology. In this analysis the four principal technological elements (GFI, 2018c) of CM are analysed: cell lines, growth media, scaffolds and bioreactors. Secondly, for *actors* and *networks*, a stakeholders analysis (Bryson, 2004) is conducted. In this context, first all the important actor groups in the CM space are described. The focus is on actor groups, not individual actors, because the number of actors in the CM space is already too high to discretely describe all of them. Key actors, however, will be pointed out. The actor groups are mapped in an interest-power matrix, as conventionally done in stakeholder analysis (Bryson, 2004). Then, the networks between these actors are tentatively described, too. Yet, as described in the section, the actor networks in the CM space are still evolving, so such an analysis is only possible in a limited way. Thirdly, institutions with relevance to CM are summarised. As described in section 2.1.2, institutions may be regulative (e.g. laws), normative (e.g. social norms) or cognitive (e.g. beliefs) (Geels, 2004). For CM, all three kinds of institutions appear important: the regulations for CM play an extremely important role and social norms for food consumptions and belief systems for food, too (Stephens et al., 2018). There are differences in the food culture between both regions (e.g. Rozin et al., 2006), but analysing them as fixed structural component does not appear to help answering the research questions of this thesis. Instead, I refer to aspects of normative and cognitive institutions in the functional analysis, for instance when discussing consumer acceptance. Hence: the institutional analysis focuses entirely on regulative institutions. Particularly, I describe the regulatory framework for CM in the USA and Europe. A similar regulatory analysis was conducted already for CM (Chatham House, 2019), albeit limited to the EU.

Not for all three components both regions are analysed separately. The technology for CM does not differ between region. It is therefore analysed without regional comparison. The actors and networks are also very similar between regions. Although I explain some regional differences, highlighting these differences is not the focus of research. Lastly, institutions. The regulatory framework differs between the two regions. For this reason, this component of the structural analysis is conducted by a regional split.

The presentation of the structural analysis in section 4 is done along the three components analysed: technology, actors and networks, and institutions. For all of these three components, literature and other information is summarised. Hence, the presentation is akin to that of a literature review (Hart, 2018).

3.3.2. Functional Analysis

The functional analysis pertains to the analysis of the seven TIS functions, as introduced in section 2.1.3. In the original formulation, the functional analysis was conceptualised as *event* analysis (Hekkert et al., 2007). Activities for each function should be mapped over time, thereby resulting in a dynamic picture of these functions over time. Such a dynamic perspective allows, for instance, to understand feedback loops between the different functions (Hekkert & Negro, 2009), the process earlier described as cumulative causation. From an analytical perspective, however, the problem is how to conduct such a dynamic analysis over time. While for certain functions such an analysis is relatively unproblematic, for instance mapping out research output by location over time, for others it is more difficult. It could be problematic, for instance, to retrospectively map out the availability of financial capital over time. In practice, this problem can be resolved by conducting several static analyses at more than one point in time (Hekkert et al., 2007). The result is a quasi-dynamic analysis of the TIS. However, the work at hand is to be conducted in a limited timeframe and therefore a dynamic analysis is not an option. The functional analysis in this work is thus a static snapshot of the IS studied. This static perspective is a major limitation of this work, which is discussed in section 7.2.2.

For operationalising the seven TIS functions, they are broken down in indicators, see Table 3-2. The indicators used for all functions besides function #4 are based on the original TIS functional analysis formulation (Bergek, Jacobsson, Carlsson, et al., 2008, 2008; Hekkert et al., 2007, 2011; Hekkert & Negro, 2009). For instance: analysing public and private research output is conventionally conducted in most TIS analyses. This original formulation is still used in recent applications (e.g. Decourt, 2019; Kao et al., 2019; Wydra, 2019). Only the indicators for function #4 were enhanced in comparison to the original formulation. Function #4, positive externalities, was part of some formulations of the TIS framework (e.g. Bergek, Jacobsson, Carlsson, et al., 2008) but not of others (e.g. Hekkert et al., 2007). Subsequently, the framework was typically more often used than not, arguably because the description of positive externalities (Bergek, Jacobsson, & Sandén, 2008) was not explicit on how it should be analysed. However, recent contributions clarified how positive externalities can be productively analysed. Two components can be considered: the contextual links of the TIS to neighboring industrial sectors (Bergek et al., 2015) – in the case of CM for instance biotechnology – and how the entrepreneurial ecosystem in which the innovations of a TIS are located support or not support innovations (van Welie et al., 2019). Both aspects are the indicators used to describe positive externalities. To evaluate the indicators, a mixture of quantitative data from the desk-research and qualifications from the interviews are used, as indicated above.

Table 3-2: Summary of TIS Indicators.

#	Function	Indicator	Description
1	Knowledge Development and Diffusion	Public Research Output	This indicator relates to scientific and technology knowledge generated in the public domain, for instance publications in peer-reviewed journals on CM. This indicator relates to learning by searching and learning by doing.
		Private Research Output	This indicator relates to scientific and technology knowledge generated in the private domain, for instance research happening in CM start-up companies. This indicator relates to learning by searching and learning by doing.

		Knowledge Exchanges	This indicator relates to activities in which the scientific and technological knowledge generated is diffused. This indicator related to learning by interacting.
2	Entrepreneurial Activity		This indicator relates to direct entrepreneurial activity: founders, start-ups, venturing arms of established companies, etc.
3	Resource Mobilisation	Financial Capital: Venture Capital Availability	This indicator relates to the availability of financial capital to begin entrepreneurial activity in the CM space, particularly the availability of venture capital (VC).
		Financial capital: research funding availability	This indicator relates to the availability of public support for research in the CM space, for instance public research funds, grants, etc.
		Financial Capital: Research Funding Availability	This indicator relates to the availability of necessary human capital to begin entrepreneurial activity in the CM space, particularly the availability of graduates.
		Physical capital and supportive infrastructure	This indicator relates to all physical resources and infrastructures that are required to start-up in the CM space and related supportive infrastructure. For CM laboratories are required and those are often found in incubators, accelerators etc. For this reason this function is conceptualised wider as maybe elsewhere.
4	Positive Externalities	Entrepreneurial Ecosystem Strength	This indicator relates to the general strength of the entrepreneurial ecosystem in each region. If a certain region has in general a strong ecosystem, all start-ups created in that area have a competitive advantage through positive externalities, particularly lower costs.
		Biotechnology Sector Strength	This indicator relates to the strength of the specific sector a company is part of, for instance in this case biotechnology. Again, a company located in a strong sector may benefit from positive externalities.
5	Legitimation	Lobbying Activity	This indicator relates to lobbying that is done for or against CM. Political functions are influenced by lobbying. Pro-CM lobbying may assure benevolent regulations, while con-CM lobbying may provoke the opposite. This function relates also to how established companies react to CM, particularly meat companies. If established players embrace CM instead of resisting it as a development, it may be easier for CM to be introduced to the market without problems.
		Reaction by the Civil Society	This indicator relates to how the civil society reacts to CM. Following conventional definitions (Ehrenberg, 2017; L. Lewis, 2005), I define the civil society as 'third sector' in addition to businesses and governments, with the exemption of lobbyists, which are mentioned in the indicator above. Specifically, this indicator refers to the reaction by media and what is typically considered the 'general public', i.e. laymen's reception of CM. If the civil society rejects CM, the probability of its market acceptance may be decreased.
6	Search Guidance	Expectations for Near-Time Development	This indicator relates to how stakeholders think how CM will develop in the near future (2-10 years from now) and what will be its long-term role. It is assumed that these expectations strongly influence for instance the availability for financial capital.
		Public Awareness	This indicator relates to whether the public is interested in CM.
7	Market Formation	Consumer Acceptance	This indicator relates to the anticipated acceptance of CM by consumers in each region. Research exists already that maps out the differences.
		Regulation	This indicator relates to what degree how easy it will be to get CM on the market from a regulatory perspective. Novel foods are typically highly regulated products, and this indicator gives justice to this fact.

As with all operationalisation, construct reliability needs to be assured (John & Benet-Martinez, 2000). A statistical validation of the indicators used in this thesis, for instance through factor analysis, is unfortunately not possible due to the limited availability of quantitative data for TIS. I return to this issue in the discussion, see section 7.2.

The presentation of the results of the functional analysis in section 5 is done as follows. The seven functions, see Table 3-2, are presented in sub-sections. For each of the functions, I then further divide the presentation of the results between those of the desk-research and of the interviews. Because the desk-research is focused on quantitative data, the presentation of these findings makes strong usage of graphics. For the interviews, I present themes that emerged in relation to the functions. For the approach used to develop these themes, see the next section on Thematic Analysis. Although I did not use strictly speaking a thematic analysis for the functional analysis, the method of how themes were derived was identical. For the interviews, I present some of the most important quotes from the interviews in the text, and summarise the remaining quotes linked to the themes in a table. Lastly, I finish all functions with an evaluation of function performance. In that sub-section, the results for each function are ranked. Firstly, I do a comparison of the USA and Europe versus the rest of the world. I allot the regions then simply the place among world regions. I consider a 1st or 2nd place to be *strong* – receiving *green*-colour coding – while a 3rd or 4th place is considered of *medium* strength – *yellow*-colour coding -, and anything below that of *low* strength – *red* colour coding. If there are only four regions considered for a certain metric, I rank everything below 3rd place as of low strength, i.e. red colour coding. Secondly, a direct comparison between the USA and Europe. Here only a binary colour coding is used: the region that leads receives a green coding, the not-leading region a red colour coding. Only if both regions are approximately equal, a blue "on pair" colour coding is used. In the end, an average of the ranking position is created for both rankings. The average of a region might be between for instance 2nd and 3rd rank. If that is the case, an in-between colour coding such as *greenish-yellow* is used, indicating for instance a *strong to medium* strength. After all functions were ranked, a total average is created. The total average does not discriminate between indicators but takes the averages of all measures used. Sometimes measures could not be evaluated, for instance between the two regions and the world; in this case they are greyed out and not used to calculate the average. If measures we qualitatively evaluated, i.e. on basis of the interviews, they were marked with an asterisk (*) but still used to calculate the average. Sometimes results from the interviews were not relevant to the function evaluation. If that was the case, they were excluded from the ranking.

3.3.3. Thematic Analysis

Thematic analysis (Guest et al., 2011; Terry et al., 2017) is a standard procedure for analysing qualitative data in the social sciences. In this thesis, I followed the three step approach as suggested by V. Braun & Clarke (2006). The first step is to derive low-order codes from the content. For coding, the content of the interview transcripts is marked. The content was coded towards answering RQ 3. Hence, only passages of the interviews that inhibited importance to the near-time development of the CM industry were marked. As mentioned above, the thematic analysis was only applied to passages not previously analysed for the functional analysis. The second step of V. Braun & Clarke (2006) is to develop higher-order themes. This step is also sometimes referred to as 'category development'. Hence, after all interview transcripts were coded for specific relevance to RQ 3, I identified common themes in the codings. For instance, two specific codings that related to a broader higher-order concept were subsumed under one theme. The process was iteratively applied: I read through all codings, and identified codings could be subsumed under one theme; then I started again from the first codings and improved the created themes. I created only themes if there were at least two independent interviewees mentioning a coding. Individual codings that could not be linked to a larger theme were discarded. The third step of the thematic analysis is the creation of a thematic map. A thematic map visually simplifies the themes that arose from the thematic analysis to support comprehension by the reader (Attride-Stirling, 2001), similar to a mind map. The three-step approach is summarised in Figure 3-2.

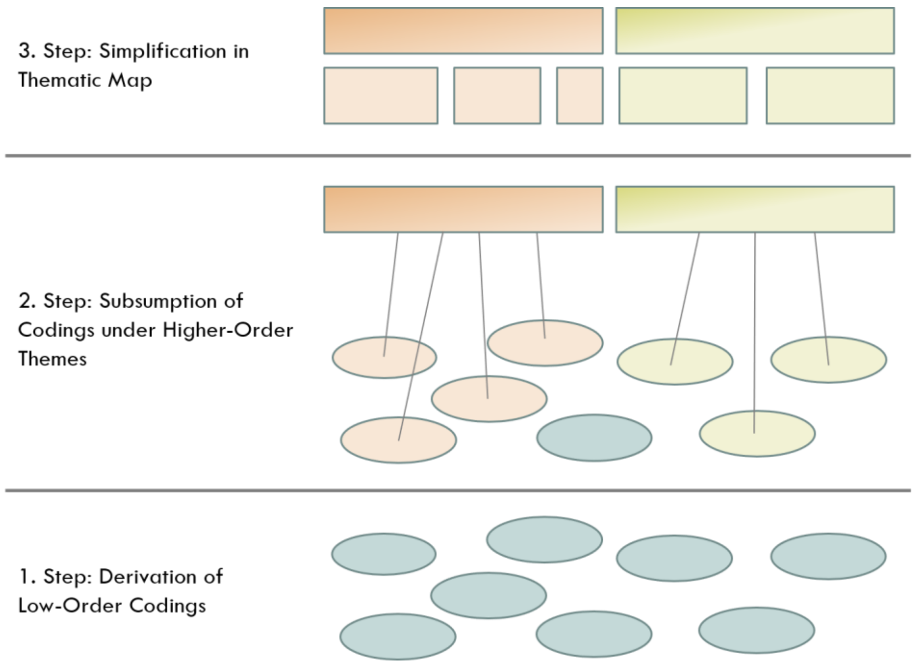

Figure 3-2: The Three Steps of Thematic Analysis.

Thematic analysis is just only possible option to inductively analyse qualitative data (Bauer & Gaskell, 2000). Two other common approaches are (critical) discourse analysis (Gee, 2014; Weiss & Wodak, 2007) and (interpretative) phenomenological analysis (Hefferon & Gil-Rodriguez, 2011; J. A. Smith, 2017). In comparison to thematic analysis, discourse analysis focuses more on the *how* than the *what*. Particularly, discourse analysis tries to analyse qualitative data in its social context. For instance: discourse analysis was applied to examine "men's talk on gender roles" in the context of the male provider role (e.g. Riley, 2003). Phenomenological analysis also focuses more on the *how* than the *what*, but in comparison to discourse analysis it focuses on how individuals create meaning rather than social context. For instance: phenomenological analysis was applied to understand how leaders develop narratives – "life-stories" – that justify and explain why they became leaders (e.g. Shamir & Eilam, 2005). Discourse analysis and phenomenological analysis differ from thematic analysis mainly by their focus on the *how* rather than the *what* and that they tend to be more interpretative. For this reason, they are no valid option for the type of analysis intended in this work.

The presentation of the thematic analysis in section 6 is done as follows. The results are summarised identical to the interview results of the Functional Analysis. Hence: selected direct quotes in the text, and all remaining quotes linked to the themes in a table. However, instead that the sub-sections are organised along the functions, they are organised along meta-themes from the thematic analysis. In addition, the section closes with a thematic map instead of an evaluation of function performance.

Having explained this thesis' data analysis approach, I next conclude this section.

3.4. Section Conclusion

This work uses two different sources in data collection, desk-research and interviews, which roughly translate into quantitative and qualitative results, respectively. Moreover, three different ways for data analysis are used: structural analysis, functional analysis – both belonging to the TIS framework – and thematic analysis.

The resulting method is summarised in Table 3-3 and linked to the research question. For answering research question 1, exclusively information from desk-research is used to conduct the structural TIS analysis. For answering research question 2, a mixture of data from desk-research and interviews is used to conduct the functional TIS analysis. For answering research question 3, exclusively data from the interviews is used to conduct a thematic analysis.

Table 3-3: Linking Research Questions to Method.

<table>
<tr><th>#</th><th>Research Question</th><th>Data from Desk-Research</th><th>Data from Interviews</th><th>Type of Analysis</th><th>Type of Reasoning</th><th>Thesis Section</th></tr>
<tr><td>1</td><td>What is the structure of the cultivated meat innovation system, specifically its technology, actors and networks, and institutions?</td><td rowspan="2">Yes</td><td>No</td><td>Structural Analysis</td><td rowspan="2">Deduction</td><td>4.</td></tr>
<tr><td>2</td><td>How does the functional performance of the cultivated meat innovation system compare in the assessed regions?</td><td rowspan="2">Yes</td><td>Functional Analysis</td><td>5.</td></tr>
<tr><td>3</td><td>What themes with importance to the near-time development of the cultivated meat industry can be identified?</td><td>No</td><td>Thematic Analysis</td><td>Induction</td><td>6.</td></tr>
</table>

Because for research questions 2 data from both desk-research and interviews is used, the two data sources complement each other. The approach is thus an iteration between both data sources, see Figure 3-3.

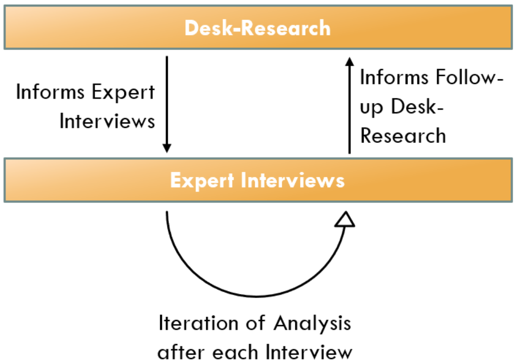

Figure 3-3: Iterative Approach for Research Questions 2.

Having described the methodology of this work, I subsequently turn to the result section.

4. Results 1: Structural Analysis

In this section I answer research question 1: *What is the structure of the cultivated meat innovation system, specifically its technology, actors and networks, and institutions?* As mentioned in section 3.1, the section on technology and actors and networks are not divided by region, and only the depiction of institutions – the regulatory framework – compares the USA and Europe. First, I provide a brief history of CM, and they dive into answering the research question.

4.1. Brief History

The idea for CM dates back at least to the early 20th. Already Winston Churchill, the later prime minister of the United Kingdom, wrote in 1932 that "we shall escape the absurdity of growing a whole chicken in order to eat the breast or wing, by growing these parts separately under a suitable medium" (Churchill, 1932).

The development of CM, however, did not receive real traction until the early 2000's (for an overview, see Stephens et al., 2019). This development became only then possible by transferring advancements in tissue engineering from medical applications to food (Stephens et al., 2018). In other words: instead of growing tissues as implant or transplant for humans, for instance skin transplant, researchers realised that one could also grow tissues for human consumption. In 2000-2001, the US' NASA founded a CM research project, aimed at potentially producing meat for long-term space flight (Stephens et al., 2019). A second milestone was the first larger funding over €2 mio. for a CM research project at Utrecht and Eindhoven University in the Netherlands. Then, famously, Mark Post, a member of that research project, mentioned in a *New Yorker* interview that CM could be produced, if only money were available (Specter, 2011). Mark Post revealed then in 2013 the first CM burger, revealing that Sergey Brin, co-founder of Google, financed the burger (Datar, 2015).

After 2013, the CM industry began to professionalise (Stephens et al., 2019). Since then, the number of start-ups is growing non-linearly, see section 5.2. State 2019, around 60 CM start-ups are active worldwide (GFI, 2019c). Some of the most notable start-ups are Memphis Meats and Finless Foods in the USA, Mosa Meat and Meatable in Europe, and Aleph Farms and SuperMeat in Israel. However, as indicated earlier, CM is not sold yet, state 2019 (GFI, 2019a).

4.2. Technology

In this section I provide a detailed overview of the production technology for CM. Because this thesis' topic is CM, the following section is more detailed compared to the other meat alternatives, which were discussed in the Background.

4.2.1. Overview of Technological System

As mentioned in the Introduction, cultivated meat (CM) is meat that is biochemically identical to conventional meat, yet grown directly from stem cells (Post, 2014; Post & Hocquette, 2017). The production of CM – or growing it – involves principally four components: cell lines, growth medium, scaffolds, and bioreactors (Arshad et al., 2017; GFI, 2018c; Post, 2012). Cell lines refer to a cell culture that can be used for CM production. Growth medium refers to the nutrient solution by which the cells are fed. Scaffolds are used fur structuring the cell's growth to take up desired forms. Bioreactor is the manufacturing device in which the cells are grown. The production process for CM needs to be thought through end-to-end. The type of species used and the desired end product influence decisions on which cells to choose, how the growth medium is formulated, and which bioreactors are appropriate. Hence: the exact assembly of the technological system may differ by use case. Figure 4-1 summarises the production process of CM, i.e. its technological system.

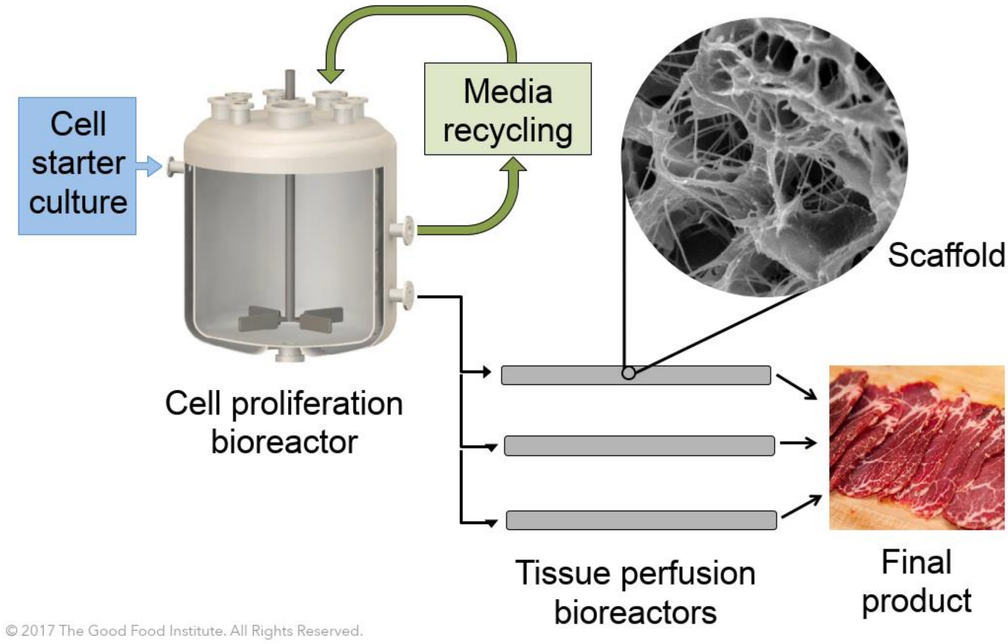

Figure 4-1: The Technological System of CM Summarised (GFI, 2017, p. 4).

CM will likely come in two generations (Gaydhane et al., 2018). The first generation are likely two-dimensional (or: unstructured) meat products such as sausage or burger patties. Such products require less sophisticated production processes and are thus the natural precursor to more complex products. Even simpler might be the production of only isolated cells, for instance fat cells, to be used as food ingredient or for other purposes. Yet, this usage is strictly speaking not cultured *meat*. The next generation will be three-dimensional (or: structured) meat products such as steak. These products are substantially more difficult to produce, because three-dimensional tissues require vascularisation (Ben-Arye & Levenberg, 2019). There is likely a substantial time-gap in market introduction of two and three-dimension CM products.

In the following, an in-depth elaboration of the four main components of CM's technological system is presented.

4.2.2. Cell Line

CM will be, as noted in the Introduction, biochemically identical to conventional meat. Principally, all animal species could be used to culture meat, for instance cow, pork, poultry – and even insects (Rubio et al., 2019). Meat tissue consists mainly of three types of cells: muscle cells (myocytes), which constitute 90% of the cells in meat tissue, and fat cells (adipocytes) and connective tissues (fibrocytes), which together make up 10% (Ben-Arye & Levenberg, 2019). Hence, culturing these cells is the goal of producing CM, with a focus on muscle cells and fat cells.

The starting point for producing CM is choosing "starting cells" (GFI, 2018c) that allow to culture the cells one is aiming at. In other words: one needs cells that can divide, multiply and differentiate into the 'target cells', for example muscle or fat cells. The starting cells need to meet two main requirements: (a) they need to be stable over time (e.g. not mutate in unintended wayss) and (b) proliferate indefinitely (i.e. being 'immortalised'). Only stem cells meet both requirements, while specialised cells do not have the capacity for both. If a stem cell culture remains stable over time and continuously proliferates, one may call it a "cell line" (Kaur & Dufour, 2012). Once a cell line is established, the cells can be continuously harvested, and are for example kept for this purpose in cell banks.

Three principal sources for cell lines for CM exist (Ben-Arye & Levenberg, 2019; Post, 2012; Stephens et al., 2018), i.e. three stem cell types. Firstly, embryonic stem cells. These cells are extracted from embryos, which typically get destroyed in the process, albeit with new approaches they may not (Dittrich et al., 2015). One can imagine embryonic stem cells as 'mother cells' from which all other cells originate: they can differentiate into all other types of cells (pluripotency). Principally, three broad categories of cells can be distinguished, depending on their function: endodermal (internal layer) cells (for e.g. lung and digestive organs cells), mesodermal (middle layer) cells (for e.g. muscles and blood), and ectodermal (external layer) cells (for e.g. skin and neuron cells). For CM, mesodermal cells are needed. Once embryonic stem cells differentiate into for instance mesodermal cells, they cannot become one of the other two types anymore, yet still all of the mesodermal group (multipotency). The further the cells differentiate, the more they lose their potential to become different types of cells. Although the usage of embryonic stem cells for CM may appear intuitively appealing – they can yield all cells, after all – in practice they are less ideal. Most importantly, the growth of embryonic stem cells is difficult to control. That they can differentiate into all types of cells makes them very prone to mutations, which accumulate by each generation (Gaydhane et al., 2018). In short: the usage of embryonic stem cells may not fulfil one of the two criteria for a cell line: stability.

Secondly, satellite cells (or: muscle stem cells) (Ben-Arye & Levenberg, 2019; Post, 2012; Stephens et al., 2018). Satellite cells are extracted via biopsy with from adult animals (GFI, 2018c), which are thought to suffer minimally or not at all from it (Post, 2014). Satellite cells are adult stem cells. In comparison to embryonic stem cells, from which tissues evolve in the first place (e.g. organs), adult stem cells can be thought of as 'maintenance cells' that keep the already evolved tissues functional by repairing them. Satellite cells repair muscles after damage. Despite often called '*muscle* stem cells', satellite cells are bipotent: they can differentiate into muscle cells (myocytes) and fat cells (adipocytes) (Tosic et al., 2018). Hence, satellite cells can be thought of as more specialised than embryonic stem cells, yet still sufficiently potent to differentiate into the types of cells one needs for CM. Again, there is a problem with satellite cells. Although they are in comparison to embryonic stem cells more stable, it is problematic maintaining their proliferation (Post, 2012). In short: the usage of satellite cells may also not fulfil the other criterion for a cell line: immortality.

Thirdly, induced pluripotent stem cells (iPSC)) (Ben-Arye & Levenberg, 2019; Post, 2012; Stephens et al., 2018). The iPSC technology is very recent and was merely developed in 2006, leading its originator, Shinya Yamanaka, to receive the Nobel prize in medicine in 2012. iPSCs are created by reprogramming already differentiated, adult cells via genetic editing to proliferate indefinitely and become pluripotent again (Ben-Arye & Levenberg, 2019). From a mere technological standpoint, iPSCs appear to be the best candidate to maintain stability and immortality. The problem with iPSCs, however, lays elsewhere: in consumer acceptance and regulatory approval. iPSCs are the result of genetic editing (Ben-Arye & Levenberg, 2019) and CM grown from them may be considered a food with GMOs. If CM is considered a genetically modified product it would be particularly problematic for Europe, see section 4.4.2.

During the CM production, cells go schematically through two phases: proliferation and differentiation (GFI, 2018c). During the proliferation (or: cell expansion) phase, the stem cells divide and multiply. At this phase, the cells will not form a structure, but remain as a cell bubble (or: 'cell mush'). During the differentiation phase, the cells become a cell type that is fit for human consumption. In this phase, the cells form structured, for instance muscle tissues. The distinction of these two phases is important because for each a different type of bioreactor is likely used, see section 4.2.5.

4.2.3. Growth Medium

The culture medium is essentially a nutrient solution that provide the cells with all required inputs to foster their proliferation and differentiation (Dove, 2014; GFI, 2019f). Contents of the culture medium are for instance amino acids, fats, salts, and, importantly, growth factors. Hence, as food does provide humans with nutrients – required energy to maintain the body's metabolism and 'building blocks' for cell construction and maintenance – so does growth medium provide cells with nutrients.

A difference to food, however, are the growth factors contained in growth medium. Growth factors are 'signalling molecules', proteins to be precise, that steer the cell's differentiation (Post, 2012). Think of the pluripotency of an embryonic stem cell: how does it 'know' to which cell it should differentiate? Growth factors – and physical cues – fulfil this function.

Critically, the ingredient mixture of the culture medium ('formulation') depends on (a) the cell types used, (b) the growth respectively differentiation stage of the cells, and (c) the animal species used (Arshad et al., 2017). Because there is no general-purpose growth medium available that suits all conditions, a CM company will require typically a growth medium specifically designed for the cells that are sought to be cultured. Hence, a growth medium with a specific formulation: a certain mixture of all relevant components (amino acids, fats, growth factors, etc.) for the cells used.

So far, the best functioning type of growth medium, which also most closely resembles a general-purpose growth medium, is fetal bovine serum (FBS) (Gaydhane et al., 2018). FBS is filtrated bovine calve blood. When cows are slaughtered but pregnant, the FBS is harvested from their calves. For doing so, a needle is injected in the calves heart and blood extracted (sic!). Calves die in the process, although they would have died also without FBS extraction, because their mothers get slaughtered. Unsurprisingly, FBS is not popular with animal rights activists (New Harvest, 2015) and likely the civil society more broadly. In addition, FBS is very expensive. Plus, if the CM is grown from iPSC or another genetically modified cell type, it falls under the Good Manufacturing Practice rules in Europe. Under these rules, the usage of FBS is likely problematic (Pachler et al., 2017). FBS has the risk of carrying animal pathogens (e.g. viruses) and there are reports of immune reactions to FBS. Although it is debatable whether these two points are still valid if FBS is merely consumed by cells early in the production process, it would likely remain a concern in Europe. For all these reasons, most if not all CM companies seek to eliminate the necessity to use FBS to grow CM.

At the point of writing, growth medium constitutes the biggest cost factor in the production of CM (GFI, 2019f): 80% of the total cost. And of this 80%, approximately 95% can be accounted for by growth factors alone (GFI, 2019f). And this 95% can be mainly attributed a very low number of different molecules. To reduce the costs associated with growth factors two strategies are imaginable. The first is to eliminate the need for growth factors, for instance by using physical cues to differentiate as wished. The second is to use growth medium recycling to re-use growth factors. It remains at the point of writing unclear which strategy will proof successful, or whether others may evolve.

4.2.4. Scaffolds

Imagine what happens if multiplying cells are left alone: the result is something like a cell ball or cell mush. To avoid this and for receiving fibrous structures, for instance muscle strings, scaffolding is required. Scaffolds provide, as the name suggests, a structure for the cell growth (Specht et al., 2018). Besides the structuration, scaffolds provide physical cues to the cells that support their differentiation process. Ideally, they are flexible and stretch the growing muscles tissues (Ben-Arye & Levenberg, 2019). They thereby support the role of growth factors. The reader may have heard that plants in a greenhouse are ventilated with direct air flow on them: without this air, they do not grow strong. Similarly, cells grow more properly if provided with physical cues. The scaffolds are typically edible and are consumed together with the final product. Both two- and three-dimension CM products require this type of basic scaffolding.

However, if more complex three-dimensional CM should be produced, scaffolds need to meet an additional requirement: vascularisation (Ben-Arye & Levenberg, 2019; Specht et al., 2018). Vascularisation means that the growing cells are supported by blood vessels that serve continuous nutrient supply and waste disposal. However, vascularisation of cell-cultured tissues is a still a relatively nascent area of research (Arkudas et al., 2015). At the point of writing one could merely speculate about how this goal should be achieved.

4.2.5. Bioreactor

The bioreactor provides a controlled environment in which the cells can be grown (Allan et al., 2019). Bioreactors are also used to produce well-known products such as beer and wine, although then they are typically called 'fermenter'. For this reason, sometimes people draw a comparison between brewing beer and growing CM (Stephens et al., 2019). In a bioreactor, not only the supply with nutrients (via growth medium) can be controlled, but also temperature, sterility, pH-value, and oxygen supply (Allan et al., 2019).

For CM production, two types of perfusion bioreactors tend to be used (GFI, 2018c). Perfusion bioreactors are in continuous operation, i.e. no batch production. In these reactors, a continuous flow of growth medium not only enables optimal supply with nutrients, but also waste removal (Allan et al., 2019).

During proliferation phase, typically fluidized bed bioreactors or packed bed bioreactors are used (Allan et al., 2019), see 'cell proliferation bioreactor' in Figure 4-1. The two reactors differ mainly in the fluid velocity used and their reactor shape, but the key design feature of both is that the cell culture remains at a stable spot. The newly proliferated cells are transported to an outlet, while the cell culture continues to proliferate.

During differentiation phase, a membrane bioreactor such as a hollow fibre bioreactor is used (Allan et al., 2019), see 'tissue perfusion bioreactor' in Figure 4-1. During the differentiation phase, more structuration of the cell's growth is required. A membrane bioreactor provides literally shaped in which cells can differentiate; a hollow fibre bioreactor, as example, funnels cell growth in hollow fibres. Membrane bioreactors therefore support scaffolds and growth factors in steering the cells to grow in desired forms.

An alternative to a bioreactor at the differentiation phase is the use of a 3D printer (Stephens et al., 2018). A 3D printer could in theory print all required tissues – muscles fibres, fat cells, blood vessels, etc. – precisely in a pattern that yielded, layer after layer, a CM product. Even three-dimensional CM products such as steak are imaginable with a 3D printer, because such a printer appears particularly promising to resolve the need for growth structuration with that of vascularization. However, here again one can only speculate about this possibility, since the 3D printing technology applied to cells is a very nascent technology, too (Patra & Young, 2016).

Having described the technology behind CM, I now turn to the second component of the structural analysis: actors and networks.

4.3. Actors and Networks

The actor groups in the CM industry mirror those in other industries. Hekkert et al. (2011) mention six actor groups that are typically found in a TIS analysis: industry, as in companies, research, education, market, as in consumers, politics/policy and intermediaries. These six groups guided the collection of actor groups that is subsequently presented.

4.3.1. Actor Groups

For CM, 10 actor groups are identified: start-ups, investors, supporting NGOs, regulatory authorities, suppliers, universities, incumbent meat producers, journalists and activist groups, CM interest groups, and farmer's interest groups. For a description of each group and important examples from both regions, see Table 4-1. The overview only entails actor groups with some degree of power and interest in the CM space. For instance: the overview considers farmer's interest groups but excludes individual small-scale farmers as a group. Individual farmers have too little power to be considered here. Moreover, the mentioned actor groups are not exhaustive and internally not complete. Not exhaustive means that there are certainly more actor groups that may influence the CM industry, albeit perhaps to a lesser degree. Note that some actors may belong to more than one actor group. Take Tyson Foods as an example: it is one of the largest US' producers of meat, but it is also one the most active investors in CM (GFI, 2019a). Most actors, however, can possibly be categorised mutually exclusively to one group. The list was created based on observations on the two exhibitions to which I went, see section 3.2.1, and from names the interviewees mentioned in the interviews.

Table 4-1: Overview of Actor Groups and Examples.

Actor Group	Description	Examples USA	Examples Europe
CM interest groups	Slowly industry associations and other interest groups for CM are evolving, which are given justice by this actor group.	Alliance for Meat, Poultry, and Seafood Innovation	Association for Alternative Protein Sources
Farmer's interest groups	Small and mid-scale farmers only gain power through interest groups. Such interest groups exist in all regions that are studied. Only larger meat producers may be able to express their interests in a meaningful way, and they are described under 'incumbent companies'.	Industry association in USA: National Cattlemen's Beef Association	On a European level: European Livestock Voice Industry associations differ by country; example for instance in Germany: Federal Association Cattle and Pork (German: *Bundesverband Rind und Schwein*)
Incumbent meat producers	Incumbent meat producers are likely negatively affected by CM. This group only entails large-scale meat companies, and not small scale independent farmers.	Tyson Foods, Cargill, JBS	PHW Group, LDC, Plukon Food Group
Investors	Investors may be investors who are exclusively invested in CM, or those who invest among other things. Investors in CM may be differentiated in a useful way for this work between impact investors, strategic investors, and for-profit investors, see section 5.3.1.	New Crop Capital, StrayDogCapital	CPT Capital
Media and activist groups	Civil society actors shape the public opinion on CM. This group entails actors with positive and negative opinions on CM.	Paul Shapiro, Friends of the Earth	Nadine Filko
Regulatory authorities	Regulatory authorities decide whether and how CM will be allowed in the market. Regulatory authorities are typically a form of governmental agency.	US Department of Health and Human Services: Food and Drug Administration (FDA); US Department of Agriculture: Food Safety and Inspection Service (FSIS)	European Food Safety Authority (EFSA)
Start-ups	The goal of these companies may be to become a focal (or 'platform', 'brand) company for CM, or to become a supplier company. For more details, see section 5.2.	US companies that received investment (GFI, 2019a): BlueNalu, Finless Foods, JUST, Memphis Meats, Mission Barns, New Age Meats, Wild Earth, Wild Type	European companies that received investment (GFI, 2019a): MosaMeat and Meatable
Suppliers	This group entails existing and potential suppliers to CM companies. Many potential actors in this group are not yet involved with the CM industry. Note that for some suppliers CM is not only an opportunity, but also a threat, particularly for pharmaceutical companies.	Thermo Fisher, GE Healthcare Life Sciences, Merck Inc	Merck Group

Supporting NGOs	There is a group of NGOs that determinedly support CM. These NGOs play a major role in shaping the evolving industry.	Good Food Institute, New Harvest, Cellular Agriculture Society	ProVeg, Cellular Agriculture UK
Universities	Public research conducted at universities and other research institutes plays an important role in shaping the CM industry.	Tufts University, Harvard University	Maastricht University, Imperial College London

The actor groups differ in the degree how they can influence the fate of the CM industry (power) and whether they have a stake in doing so (interest). Figure 4-2 maps the 10 actor groups by their power and interest in a matrix, based on my interpretation. The matrix does not show how interested an actor group *ought be* in CM in my opinion, but how interested the actor group appears currently to be in CM, on average for all actors it entails. An actor group might exert directly or indirectly influence on the CM industry. Take farmer's interest groups as an example: although they cannot influence the operation of CM start-ups, they can lobby policymakers, and thereby influence potentially the regulation of CM.

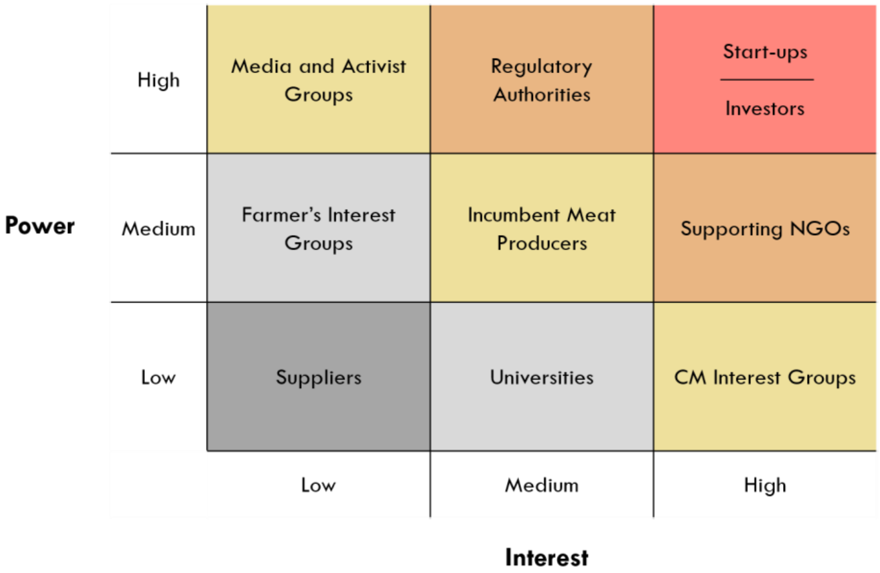

Figure 4-2: Actor Groups mapped by their Power and Interest. (For reasoning behind mapping, see Appendix B)

Next, I discuss actor networks.

4.3.2. Networks

In addition to actors, networks between them should be analysed (Hekkert et al., 2011). In terms of networks, Bo Carlsson et al. (2002) differentiate between buyer-supplier relationships, informal networks, and problem-solving networks. Firstly, buyer-supplier relationships. These are in the CM industry so far only existing in a limited way, as the industry is nascent. No supply chain exists yet, for instance. As I explain in section 4.2, the CM industry is still deep in the research and development (R&D) phase. Hence, these networks are not of high importance. Secondly, informal networks. These are for instance established on industry conferences. Informal networks play an important role in the CM industry – yet are difficult to be analysed. One example: there are email lists and Slack group chats for people interested in the CM space in Europe, through which one can only gain access by speaking with the right people on CM conferences. However, one can hold that the starting point of these informal networks are in many if not most cases formal knowledge exchanges and meet-ups on CM, such as conferences. I elaborate on these in section 5.1.3. Lastly, problem-solving networks. According to Bo Carlsson et al. (2002) this is the type of network that actually defines the boundaries of an IS, and therefore of the CM industry. In my interpretation, the main problem-solving network in the CM industry exist between CM start-ups, investors, supporting NGOs, CM interest groups, and partially universities and suppliers. These six actor groups are either working directly (e.g. CM start-ups with suppliers and partially universities) or indirectly (e.g. CM start-ups with investors, supporting NGOs, and CM interest groups) together on advancing the CM industry. The resulting problem-solving networks are illustrated in Figure 4-3.

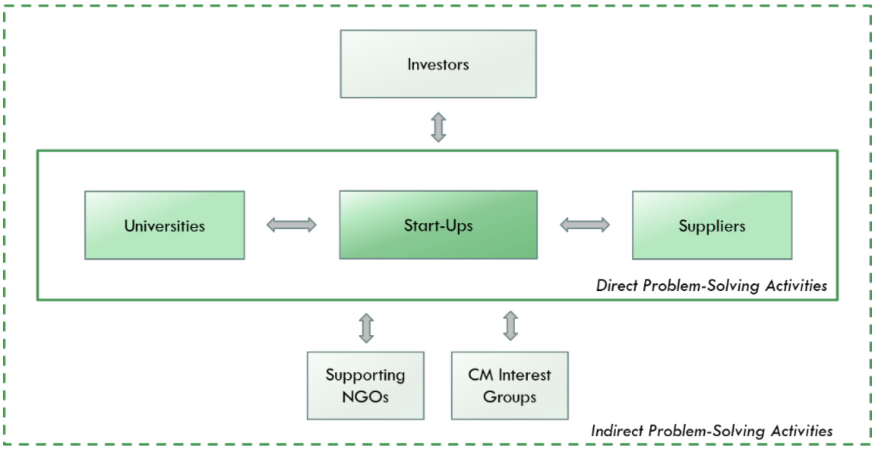

Figure 4-3: Problem-Solving Networks for CM.

Overall, it can be said that the networks for CM, be it direct or indirect problem-solving activities, are still under development. In the data collection for this thesis, the networks that (a) arose from interactions on CM conferences and (b) were facilitated by pro-CM NGOS, particularly the GFI, proved to be the most important. The CM space was at the point of writing still small, and one ‘knew each other’ after a quite short period of time. For instance: the total number of people active in the CM space in Europe was in 2019 arguably substantially less than 1000; probably a few hundred. One can imagine how informal the networks are at this stage. In the USA the total number of people active in the CM space were probably a bit higher, albeit also centred around conferences and key start-ups.

Having described the actors and networks in the CM industry, I subsequently turn to the institutions operating on them.

4.4. Institutions

In this section, I focus on the regulatory framework in each region, as mentioned in section 3.3.1. The regulatory framework in both the US and Europe is an application of food law.

4.4.1. USA

As mentioned in Table 4-1, the key regulatory authorities for food in the USA are the US Department of Health and Human Services’ Food and Drug Administration (FDA) and the US Department of Agriculture’s Food Safety and Inspection Service (FSIS). The FDA regulates about 80% of all food, while the FSIS regulates meat, poultry and eggs (European Parliament, 2015). Federal regulations govern whether a food can be sold across different states (‘interstate commerce’) and the import from and to other countries; state and local regulations govern sales within a given state (‘intrastate commerce’) (European Parliament, 2015). While the FDA conducts for instance inspections and regulations for foods under their authority, the FSIS does the some for the meat, poultry and egg products under their authority. However, if FDA regulates most food and FSIS regulates meat, which authority regulates CM?

The situation was clarified in March 2019: FDA and FSIS will regulate CM together (FDA, 2019). While the FDA will oversee the regulation of CM until the animal cells are grown (process), the FSIS will oversee their further downstream processing, including labelling (product). In their agreement, FDA and FSIS mention that they will both regulate the safety of CM products together (FSIS, 2019), which will most likely include a premarket approval process.

What the premarket approval may contain can be inferred from how the FDA normally regulates new foods and food ingredients. Unless a new food has the status as "generally recognised as safe" (GRAS), it needs to go through a premarket approval process by the FDA (FDA, 2018b). GRAS status is only granted if "the scientific data and information about the use of a substance [is] widely known and there [is] a consensus among qualified experts that those data and information establish that the substance is safe under the conditions of its intended use" (FDA, 2018a). Although CM might be considered GRAS in the future, it is unlikely to be considered as such before market introduction. In the premarket approval process (Neltner et al., 2011), foods are compared under the principle of "substantial equivalence" to their conventional counterparts. This means that CM would be compared to conventional meat regarding its allergenicity, toxicity, etc. The substantial equivalence considers also genetic modifications as "extensions … [of] traditional plant breeding" (FDA, 1992), because plant breeding, as genetic engineering, interferes with an organism's genetic code.[13] Hence, if CM will be produced using genetic modifications, it will not be evaluated differently: foods containing GMOs are also compared by the principle of "substantial equivalence" to their conventional counterparts. The duration of the approval process in the US is not pre-defined, but taking GMOs as a measure, it may take three years for approval (Dobert, 2015). The labelling of CM will likely be defined in the meantime by FSIS.

4.4.2. Europe

The main regulatory authority that will oversee CM in Europe is the European Food Safety Authority (EFSA), as mentioned in Table 4-1.[14] CM will need to go through one of two approval processes before it can be sold in Europe: either through the novel food regulation approval process, or the GMO approval process (Chatham House, 2019).

For both novel food regulation and GMO approval process, the CM needs to go first through a risk and safety assessment by the EFSA, which is very similar to that of the FDA. For their safety tests, the EFSA assessment also rests on the substantial equivalence principle (EFSA, 2013). The duration of the safety assessment of EFSA is about 9-10 months (Chatham House, 2019), unless EFSA requires more time to conduct the assessment.

After the risk and safety assessment, the EFSA sends their results to the European Commission for decision, particularly its Standing Committee on Plants, Animals, Food and Feed (European Commission, n.d.-b). The decision by the standing committee should be reached within 7 months (Chatham House, 2019). It should be noted that this step of the regulation is not purely objective anymore. Whether the standing committee follows the recommendation of EFSA is basically a political process. Overall, the process from application to approval should take 18-24, factoring already possible delays in.

The GMO approval process is different in one critical point: the member states of the EU can opt out of their usage on their territory (European Commission, n.d.-a). In other words: even if GMO-containing CM would be 'allowed' on a European level, individual states could disallow its usage. Critically, the process would become in such a situation even more politically. While EFSA and the standing committee of the European Commission are likely relatively detached from voter's wishes, this is arguably not necessarily the case for national governments. GMOs face strong public resistance

[13] Wether GMOs are safe for human consumption is an ongoing debate (Hilbeck et al., 2015; Krimsky, 2015; Nicolia et al., 2014; Panchin & Tuzhikov, 2017; Tagliabue, 2016) whose details are out of scope for this work.
[14] The regulation in Europe described here refers to the regulation in the European Union.

in Europe (Bonny, 2003; Mohorčich & Reese, 2019; Tosun & Shikano, 2016). Hence, it is not granted that CM could be sold in Europe if it contains GMOs, even it is considered harmless by EFSA.

4.5. Section Conclusion

This section sought to answer research question 1: *What is the structure of the cultivated meat innovation system, specifically its technology, actors and networks, and institutions?* I subsequently answer the research question by its three components. In addition, this section provided a brief history of CM.

Firstly, the technology. The analysis revealed that key principles of the structure of CM's technological system are defined, yet in detail many uncertainties prevail. It is certain that some sort of cell line, growth medium, scaffold, and bioreactor are required. But it appears that most of the details are not yet set in stone. Various options exist for every single of the four components. In addition, the section did not even discuss the upstream production of these components themselves. For instance: even if a perfect growth medium formulation is derived and the growth factor costs substantially reduced, there is not yet a production process for large-scale growth medium production in place (Specht et al., 2018). The growth medium volumes that are likely needed for CM exceed those in typical applications of growth medium in the pharmaceutical industry likely by orders of magnitude (GFI, 2019f). In conclusion, the broad concept of CM's technological system is clear, while its details remain largely uncertain at the point of writing.

Secondly, actors and networks. The stakeholder analysis showed that distinct actor groups concerned with CM are already identifiable. CM start-ups, investors in CM, supportive NGOs and regulatory authorities can be pointed out as those actor groups that combine a relatively high degree of power and interest. The analysis also showed that of all actor groups, important examples can be identified in both the USA and Europe. Hence, there is no clear discrepancy between one region or another observable. On the side of actor networks, things appear less certain. Problem-solving networks are existing. On a technological side, CM start-ups, universities and suppliers work on directly solving the problem of advancing CM. Peripherally, they are further supported by CM investors, supporting NGOs and CM interest groups. Overall, it appears, state now, that clear actor groups have already evolved. However, it appears that formal networks are still under development, and it is uncertain how exactly things will play out in this regard, for instance regarding industry associations.

Lastly, institutions. In this section I described the regulatory framework for CM in the USA and Europe. In both regions, who will regulate CM is defined. In the USA, it will be a combination of oversight by the FDA, controlling the upstream process, and the FSIS, controlling the downstream product. The process can likely be politically influenced, but only indirectly. In the USA, a CM product that contains GMOs will likely not be vastly problematic, while it probably be the case in Europe. The regulatory approval process in the USA will arguably take up to three years. In Europe, the EFSA and the European Commission oversee CM's regulation. EFSA is responsible for the risk assessment and based on that gives a recommendation to the European Commission. The process is at the EFSA level likely unpolitical, but it can get politically influenced at the level of the European Commission. A CM product that contains GMOs will likely be a problem in Europe, because even if it gets permitted, each individual national state can disallow their usage. The regulatory approval process will likely take 18-24 months in Europe. Overall, the regulatory framework for CM is clear in the big picture, but details remain uncertain and will only become clear after a request to allow CM in each region is filed.

The answer to research question 1 is thus in summary that overall the key aspects of CM's technology, its actors and networks, and institutions are clear, but many details remain uncertain. Having answered conducted the structural analysis, I turn in the next section to the functional analysis.

5. Results 2: Functional Analysis

In this section I answer research question 2: *How does the functional performance of the cultivated meat innovation system compare in the assessed regions?* The section is divided into seven sections that correspond to the seven functions, as introduced earlier (see section 2.1.2 and 3.3.2). In this section, I may refer to other regions than the USA and Europe, where appropriate or relevant. For each function, I go through each indicator, presenting results from desk-research and interviews, and then conclude each function with an evaluation of the function performance. In the section conclusion, see 5.8, the regions are compared in summary and the answer to the research question provided.

5.1. Function #1: Knowledge Development and Diffusion

5.1.1. Public Research Output

Desk-Research

How strong is the public research output for CM in the USA and Europe? To quantitatively evaluate the public research output, I conducted a bibliometric publication analysis of science, technology, engineering and mathematics (STEM) publications regarding CM with Scopus, an academic search engine. See Appendix C for methodological notes of this bibliometric analysis including exact queries.

Figure 5-1 shows the number of worldwide publications on CM since 2007. In total 155 publications were found, of which 79 (51%) were published within the last three years. From 2007 to 2019 the number of publications grew with a compound annual growth rate of 37%. Overall, the figure shows that one can observe a strong growth in the number of publications. However, there were significant dips in the number of publications in 2014 and 2016.

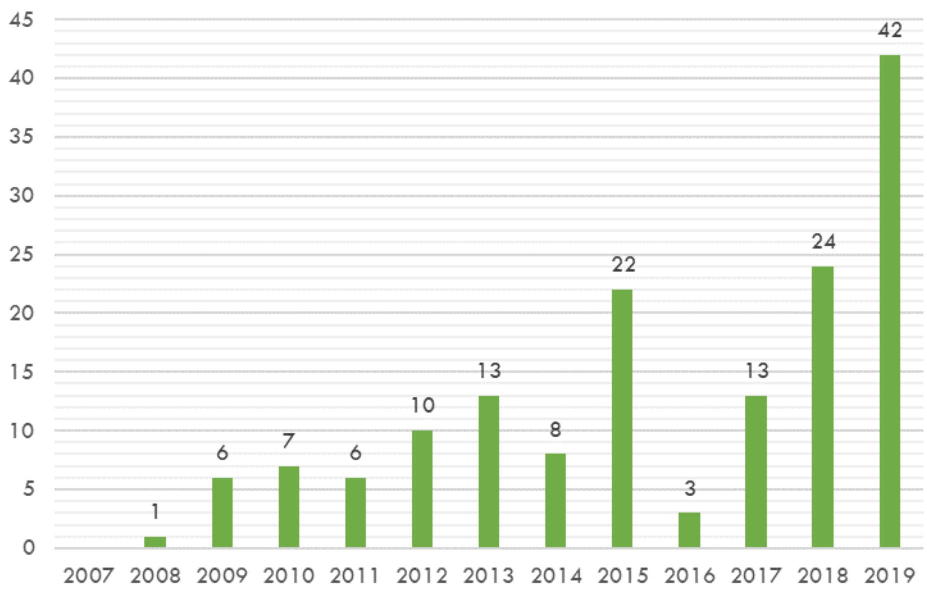

Figure 5-1: Number of CM Publications since 2007.

Figure 5-2 shows the geographical distribution of STEM-related research on CM based on university affiliation.[15] Based on this data, Europe appears to be clearly leading in public research on CM, and USA and the Asia-Pacific regions appears on pair. Israel, although apparently important in private research (see section 5.1.2), has an insignificant number of publications.

[15] Because many publications had authors coming from different regions, the number of counted publications here was 202, not 155.

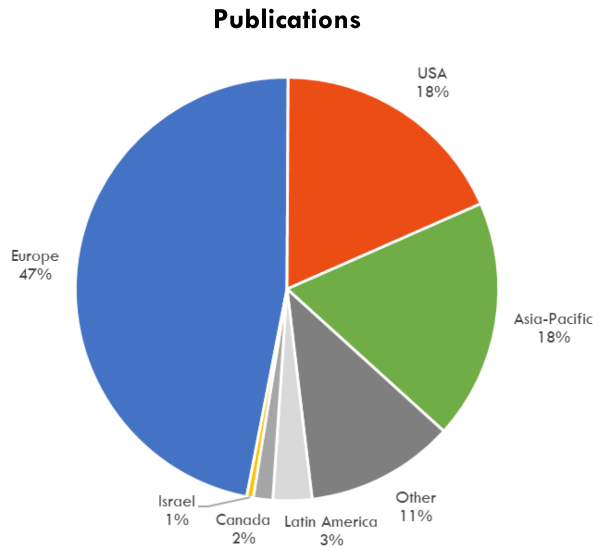

Figure 5-2: Geographical Distribution of CM Publications since 2007.

Next, I evaluated with which research organisations (universities, research institutes, NGOs, etc.) the publications were associated. A total of 150 different affiliations were counted. With 117 (78%) only one publication was associated. For 16 (11%) only two publications were counted. Table 5-1 below shows the remaining 17 (11%) research organisations with more than two publications on CM.

Table 5-1: Research Organisations with more than two CM Publications.

#	Affiliation	Region	Country	Number of Publications
1	INRA Institut National de La Recherche Agronomique	Europe	France	11
2	Sher-e-Kashmir University	Asia-Pacific	India	10
3	Wageningen University & Research	Europe	Netherlands	9
4	University of Bath	Europe	United Kingdom	6
5	University of Oxford	Europe	United Kingdom	5
6	Arizona State University	USA	USA	4
7	Linköping University	Europe	Sweden	4
8	University of Kashmir	Asia-Pacific	India	4
9	Maastricht University	Europe	Netherlands	4
10	Brunel University London	Europe	United Kingdom	4
11	Tufts University	USA	USA	4
12	VetAgro Sup	Europe	France	4
13	University of Helsinki	Europe	Finland	3
14	Colorado State University	USA	USA	3
15	Murdoch University	Asia-Pacific	Australia	3
16	Universiteit Gent	Europe	Belgium	3
17	The Good Food Institute	USA	USA	3

Figure 5-3 summarises the regional location of these leading research organisations. Europe hosts the highest number of leading research organisations (59%), the USA comes second (23%) and Asia-Pacific third (18%). Within this group of very active research organisations in CM, there is an almost equal split of about 13 to 15 publications that can be associated with organisations in the United Kingdom (15), France (15), USA (14), India (14), and the Netherlands (13), with the rest going to other countries in Europe (13) (not in the graphic, see Table 5-1).

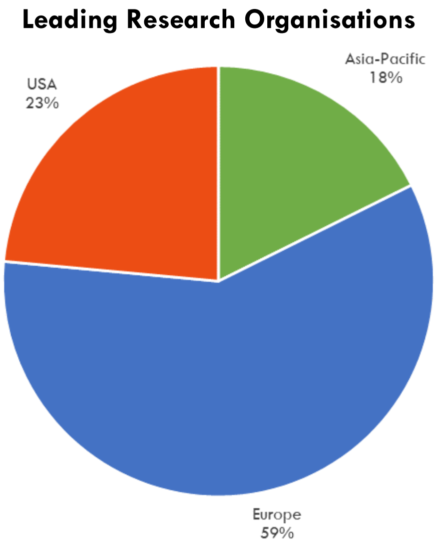

Figure 5-3: Geographical Distribution of Leading Research Organisations.

Having explored the quantitative data on public research on CM, I turn now to the results of the interviews.

Interviews

The interviews revealed one theme relating to public research on CM: *there is little relevant publicly available research on CM, yet research activity is growing*, see Table 5-2. This theme is directly confirming the quantitative results and almost reads like a summary of them. Within this quite general theme there is, however, one more specific insight:

> Interviewee 9 (researcher): *"And the academic side … [there] are still very few what I'd call fundamental peer-reviewed papers that provide the foundation for the field."*, quote #2, Table 5-2

Hence, taking the low quantity of public research aside, this quotes to something else: that the existing research is in terms of impact or importance low.

Table 5-2: Themes Public Research Output.

Theme	Quotes	#
1: There is little relevant publicly available research on CM, yet research activity is growing	Interviewee 5 (non-governmental organisation [NGO] employee): *"If you and I had spoken last year around this time, I would have said [that] there is like really no research happening anywhere except maybe for Mark Post, right? And now we're starting to see more. I mean, even just in the past couple of weeks, right? Research is happening in more labs around the world."* [21:33]	1
	Interviewee 9 (researcher): *"And the academic side … [there] are still very few what I'd call fundamental peer-reviewed papers that provide the foundation for the field."* [01:25]	2
	Interviewee 10 (NGO employee): *"There are very, very few scientific publications [on cultivated meat]"* [03:08]	3
	Interviewee 17 (supplier employee): *"I've seen very little [research on cultivated meat]. There is plainly very little."* [50:44]	4

Next, I explore the private research output on CM.

5.1.2. Private Research Output

Desk-Research

How strong is the private research output for CM in the USA and Europe? Similar to public research output, I sought to quantitatively evaluate the research output of private actors, in this case through a patent analysis, which naturally focuses on STEM. For analysis, I used the databases Depatisnet[16] and Patentscope[17] that both allow to search worldwide patent applications, complemented by a pre-existing patent analysis by stakeholders in the CM space[18]. See Appendix D for methodological details on the patent analysis.

Figure 5-4 shows the number of patents on CM since 2007. A total of 20 patents were filed since 2007, whereas 7 (35%) were filed in the last three years. Overall, the figure shows a growing trend in patent applications. However, the growth is inconsistent, with four years of no patent application since 2009. Moreover, the number of patent applications in 2018 was declining in comparison to the two years before, and in 2019 *no* patent was filed, at least none that was findable in the three used data sources.

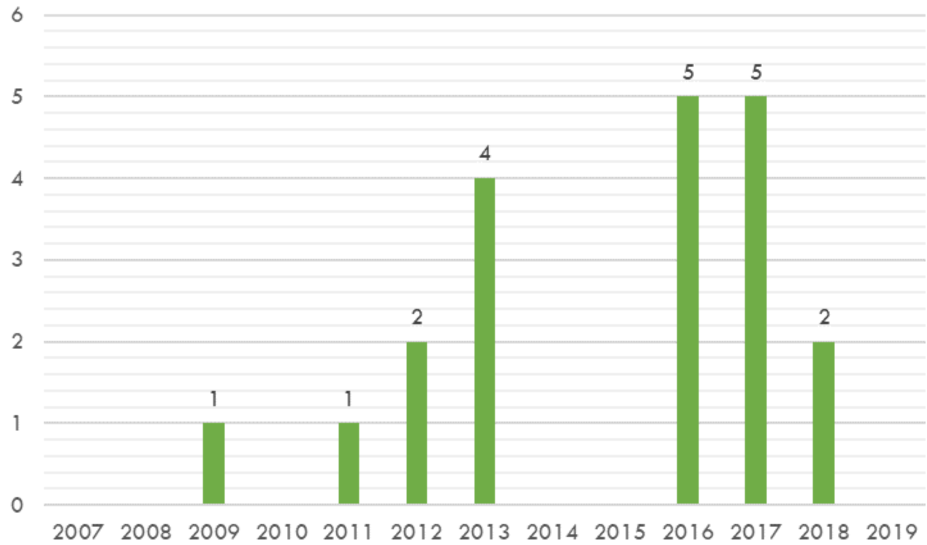

Figure 5-4: Number of CM Patents since 2007.

Figure 5-5 shows the geographical distribution of CM patents. As visible in the graph, most patents were filed from organisations in the USA (60%), with Israel coming second (20%) and Europe and Asia-Pacific sharing a third place (both 10%).

[16] Available online at: https://www.dpma.de/english/search/depatisnet/index.html; accessed 24/01/2020
[17] Available online at: https://www.wipo.int/patentscope/en/; accessed 24/01/2020
[18] Available online at: https://www.culturedabundance.com/; accessed 24/01/2020

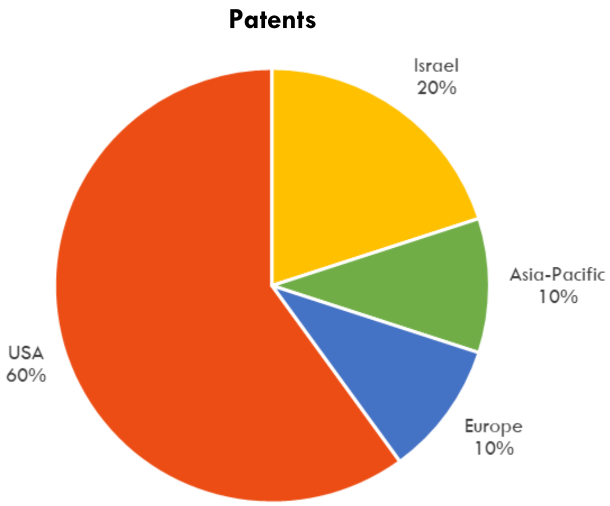

Figure 5-5: CM Patents by Region since 2007.

Lastly, I analysed the organisational affiliations of the patents. A total of 12 organisations hold ownership in the 20 existing patents. Of these 12, nine hold only one patent. Table 5-3 shows the remaining three organisations with more than one patent on CM. The dominance of the USA in patent applications also translated into dominance in firms with more than one patent.

Table 5-3: Organisations with more than one CM Patent.

#	Affiliation	Region	Country	Number of Patents
1	Modern Meadow	USA	USA	5
2	Memphis Meats	USA	USA	4
3	Aleph Farms	Israel	Israel	2

Having explored the quantitative data on private research on CM, I turn now to the results of the interviews.

Interviews

Regarding private research, the interviews showed one theme: *the exact state of private research is not knowable, but Israeli companies appear to be leading*, see Table 5-4. That the exact state is not knowable appears to arise from the simple fact that private research on CM is *private* and firms do not openly publish their state of research:

> Interviewee 9 (researcher): *"[Regarding the state of private research on CM] I wish I knew, and that's a great question. You know, the private folks are private. You don't really know where they're at. (…) Many of them file patents and patents are only good for so much. (…) We have no way of knowing."*, quote #1, Table 5-4

In addition, several participants voiced their opinion that Israeli' companies are ahead in terms of state of their research:

> Interviewee 8 (supplier employee): *"We have spoken to 70 percent of all [cultivated meat] companies that everybody's aware of. (…) We felt that the three Israeli start-ups, Aleph Farms, Super Meat and Future Meat Technology, are the best of all companies that we have spoken to. (…) It seems like the Israeli companies really know what they're doing."*, quote #4, Table 5-4

> Interviewee 10 (NGO employee): *"I think we have some well advanced that companies in Israel."*, quote #5, Table 5-4

However, unfortunately there is not really any possibility to explore these statements further. Are Israeli start-ups objectively ahead of others? As it is with trade secrets: *"We have no way of knowing"*, as one interviewee noted (quote #1, Table 5-4).

Table 5-4: Themes Private Research Output.

Theme	Quotes	#
1: The exact state of private research is not knowable, but Israeli companies appear to be leading	Interviewee 9 (researcher): *Regarding the state of private research on CM: "I wish I knew, and that's a great question. You know, the private folks are private. You don't really know where they're at. (…) Many of them file patents and patents are only good for so much. (…) We have no way of knowing."* [08:15]	1
	Interviewee 15 (NGO employee): *"I think a lot of big drug companies have developed cell culture media for human use years ago (…) And they're working on getting those prices down so that they can provide to the industry, but I don't have a great grasp on exactly what's happening there because a lot of that research would have IP [intellectual property] protection."* [29:09]	2
	Interviewee 5 (NGO employee): *"I think Israel (…) is like in general a year or two ahead of any European country just because there are already companies that are relatively mature."* [19:56]	3
	Interviewee 8 (supplier employee): *"We have spoken to 70 percent of all [cultivated meat] companies that everybody's aware of. (…) We felt that the three Israeli start-ups, Aleph Farms, Super Meat and Future Meat Technology, are the best of all companies that we have spoken to. (…) It seems like the Israeli companies really know what they're doing."* [53:44]	4
	Interviewee 10 (NGO employee): "I think we have some well advanced that companies in Israel." [12:35]	5

Next, I explore knowledge exchanges with relevance to CM.

5.1.3. Knowledge Exchanges

Desk-Research

How well developed is the knowledge exchange for CM in the USA and Europe? Similar to the two sections above, I sought to quantify the knowledge exchanges on CM. Because informal meetups and smaller sized events are difficult to track, I focused on international conferences about CM. I took a publication by Stephens et al. (2019) as starting point, which mapped out the historic development of the CM space, and conducted additional online searches. See Appendix E for further methodological notes and the entire list of conferences that we found.

Figure 5-6 summarises the number of conferences on CM in a given year since 2007. I counted a total of 21 conferences that happened on CM so far, with the first one happening in 2015. The compounded annual growth rate of yearly conferences was 48%.

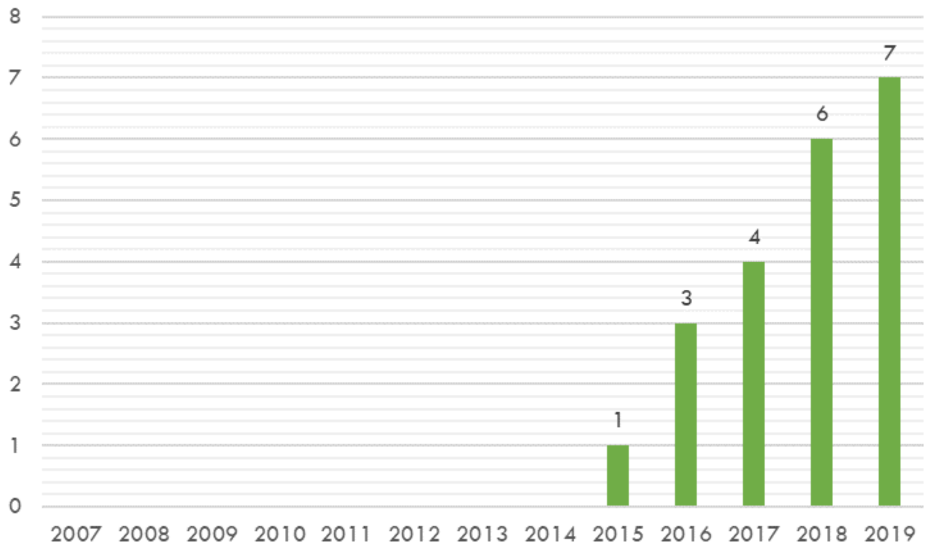

Figure 5-6: Number of CM Conferences since 2007.

Figure 5-7 summarised the geographical split of these 21 conferences. The graphic shows that the total number of conferences that happened so far is highest in Europe (52%), directly followed by the USA (43%) while Israel came last (5%). No other region worldwide hosted international conferences on CM yet.

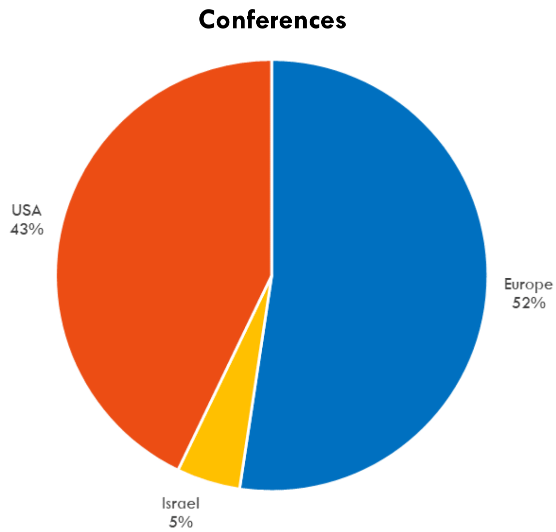

Figure 5-7: CM Conferences by Region since 2007.

A higher share of conferences can be attributed to Europe over the years mainly because the world's first international conference, the International Scientific Conference on Cultured Meat, started already in 2015 in the Netherlands. At the end of 2019, there were a total of seven ongoing conferences on CM, with four (57%) in the USA and three (43%) in Europe, see Table 5-5.

Table 5-5: International CM Conferences State 2019.

Conference	Region	Country	First Year
International Scientific Conference on Cultured Meat	Europe	Netherlands	2015
New Harvest Conference	USA	USA	2016
Cultivate	Europe	United Kingdom	2016
Good Food Conference	USA	USA	2018
Cultured Meat Symposium	USA	USA	2018
New Food Conference	Europe	Germany	2018
Industrializing Cell-Based Meat Summit	USA	USA	2019

Having also explored this data set, I come now to the interviews.

Interviews

The results of the interviews revealed two themes regarding knowledge exchange. These themes are not much concerned with the conferences, but more with the knowledge exchanges between companies. Most interviewees typically referred to as the most important conferences as those in the USA and the one conference in the Netherlands. See Table 5-6 for the quotes.

The first theme is that *there is not too much collaboration among CM start-ups, yet a friendly spirit*. One interviewee summarised the whole situation and its causation very well:

> Interviewee 15 (NGO employee): *"I think some of it has to do with these companies wanting the first mover advantage. Because there's not a ton of collaboration happening. They don't know where they stand against their competitors. If you file a patent that information becomes public. But if this company thinks that they're the only one who's going to be able to develop this is than their incentive is to keep the trade secret instead (…). And so they have to be careful to not divulge that information. I think a lot of it has to do with the venture capital model. Venture capitalists (…) their incentive is to make sure that one company (…) succeeds and not necessarily the whole industry. (…) Their [CM start-ups] hands are a little bit forced to not collaborate. But despite what's happening on the IP [intellectual property] front, there is a spirit of collaboration or at least mutual support in the industry. You have all these conferences - like the New Harvest Conference, Cultured Meat Symposium, the Good Food Conference – that most of these or at least a lot of these companies go to and they all collaborate and discuss. (…) The founders themselves for the most part are really mission oriented and they want to collaborate and they want the whole industry to succeed."*, quote #3, Table 5-6

The second theme that evolved is a qualification of the first theme: that *European and Israeli companies more open than US' companies*. There was no clarity whether Israeli or European companies are the most collaborative, yet interviewees tended to agree that both are more collaborative than US firms:

> Interviewee 7 (journalist): *"Everybody [CM start-ups] is very secretive. That's my feeling. But Israeli are (…) more open than others."*, quote #4, Table 5-6

> Interviewee 17 (supplier employee): *"The Israelis are very open until now. But I'd say that Europeans are also more open than the Americans."*, quote #5, Table 5-6

Table 5-6: Themes Knowledge Exchanges.

Theme	Quotes	#
1: There is not too much collaboration among CM start-ups, yet a friendly spirit	Interviewee 1 (investor): *"These companies are not really competing with each other on consumer dollars because the market share of cultivated meat is not precisely zero point zero zero zero zero zero percent. What they're really competing for his investor's dollars at this stage. (….) Because investors don't have the checkbooks to invest in 60 companies globally."* [03:22]	1
	Interviewee 3 (entrepreneur): *"Then [there] is some amount of friendliness, [but] at the same time, there's also a lot of secrecy between the companies (…) In the long-term we're really all competing against traditional meat. (…) We are still competing for funding and financing and people. There is a certain amount of competition, but it's pretty friendly competition."* [06:56]	2
	Interviewee 15 (NGO employee): *"I think some of it has to do with these companies wanting the first mover advantage. Because there's not a ton of collaboration happening. They don't know where they stand against their competitors. If you file a patent that information becomes public. But if this company thinks that they're the only one who's going to be able to develop this is than their incentive is to keep the trade secret instead (…). And so they have to be careful to not divulge that information.*	3

	I think a lot of it has to do with the venture capital model. Venture capitalists (…), their incentive is to make sure that one company (…) succeeds and not necessarily the whole industry. (…) Their [CM start-ups] hands are a little bit forced to not collaborate. But despite what's happening on the IP [intellectual property] front, there is a spirit of collaboration or at least mutual support in the industry. You have all these conferences - like the New Harvest Conference, Cultured Meat Symposium, the Good Food Conference – that most of these or at least a lot of these companies go to and they all collaborate and discuss. (…) The founders themselves for the most part are really mission oriented and they want to collaborate and they want the whole industry to succeed." [18:14]	
	Interviewee 7 (journalist): *"Everybody [CM start-ups] is very secretive. That's my feeling. But Israeli are (…) more open than others."* [09:06]	4
2: European and Israeli companies more open than US' companies	Interviewee 17 (supplier employee). *"The Israelis are very open until now. But I'd say that Europeans are also more open than the Americans."* [37:34]	5
	Interviewee 20 (investor): *"I think a typical difference between the Americans and the Europeans is that Americans are very careful not to exchange information because they're afraid someone could surpass them. And in contrast some European firms rather take a collaborative approach"* [24:24]	6

Having explored all indicators for the function, I now turn to the evaluation of the function performance.

5.1.4. Evaluation of Function Performance

How does the knowledge development and diffusion differ between the USA and Europe? Overall, it appears that the USA is leading, with some notable exceptions. Firstly, public research output, the exemption. Europe is leading in total number of publications (Figure 5-2) and number of leading research organisations (Figure 5-3). Secondly, private research output. On this the USA is leading in total number of patents (Figure 5-5) and individual patent holding organisations (Table 5-3). However, interviewees noted that Israeli companies are leading in research, not US' or European'. Lastly, knowledge exchanges. The USA is leading in the number of continuously held conferences on CM (Figure 5-7), albeit only slightly. Yet, Israeli and European start-ups are noted to be more open in knowledge exchagnes than US. Overall, it appears that the US is leading in terms of knowledge development and diffusion for CM compared to the rest of the world and versus Europe, see Table 5-7.

Table 5-7: Performance of Function 1: Knowledge Development and Diffusion.
(For ranking methodology, see section 3.3.2)

#	Function	Indicator	Measure	Comparison vs. Rest of the World		Comparison USA vs. Europe	
				USA	Europe	USA	Europe
1	Knowledge Development and Diffusion	Public Research Output	Number of publications	2nd / 3rd	1st	Not leading	Europe leading (161% stronger)
			Leading research organisations	2nd	1st	Not leading	Europe leading (157% stronger)
		Private Research Output	Number of patents	1st	3rd / 4th	USA leading (500% stronger)	Not leading
			Leading patent-holding organisations	1st	3rd / 4th	USA leading	Not leading
			Leading in technology	2nd / 3rd *	2nd / 3rd *	Not compared	
		Knowledge exchanges	Number of hosted conferences	1st	2nd	USA leading (33% stronger)	Not leading
			Openness among start-ups	3rd	1st / 2nd	Not leading*	Europe leading*
		Total average		1st	2nd	USA leading	Not leading

* Based on qualitative data from the interviews.

In the next section I explore the results for the second function, entrepreneurial activity.

5.2. Function #2: Entrepreneurial Activity

5.2.1. Entrepreneurial Activity

Desk-Research

How strong is the entrepreneurial activity for CM in the USA and Europe? To evaluate the entrepreneurial activity on CM, I explored four datasets: the number of companies in each region, the number of employees by company, the investments by company and the role of the company in CM's supply chain. The datasets together show the strength of entrepreneurial activity, give some indication of the start-up quality, i.e. the degree of professionalisation and potentially success probability, and the type of CM-related entrepreneurial activity in each region. The total list of start-ups can be found in Appendix F.

Figure 5-8 provides an overview of the number of CM start-up by region. I again also show the companies besides the USA and Europe to allow an international comparison. There are in total 60 CM start-ups active globally, status end of 2019. The USA and Europe host with 34% respectively 32% the highest number of CM start-ups worldwide and are both approximately equally strong. This data strengthens the case that the USA and Europe are the strongest regions for CM worldwide.

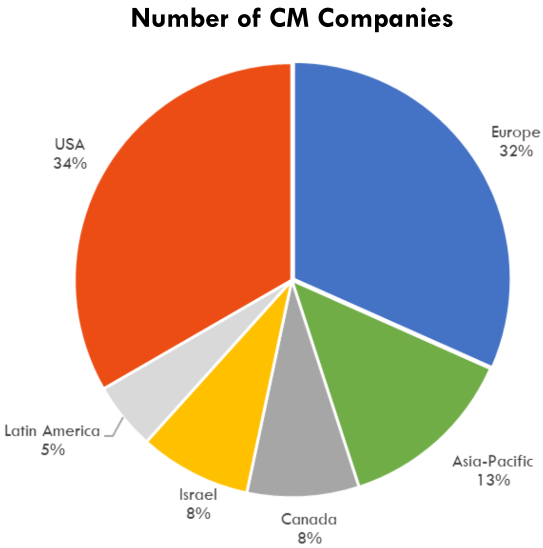

Figure 5-8: Number of CM companies by Region.
(With data from GFI, 2019c, 2019a)

Figure 5-9 shows the total number of people employed in CM companies by region, with data scraped from LinkedIn, an online career network. For methodological notes, see Appendix G. In total, 460 people work according to this search in the CM industry. Again, the USA and Europe are leading with 43% respectively 33% of all employees. However, on this metric, US start-up have in total 31% more employees than those in Europe (USA: 196; Europe: 150). Although this data so far shows a strong advantage of the USA and Europe compared to other regions, it does not tell much about the quality of the start-ups in each region.

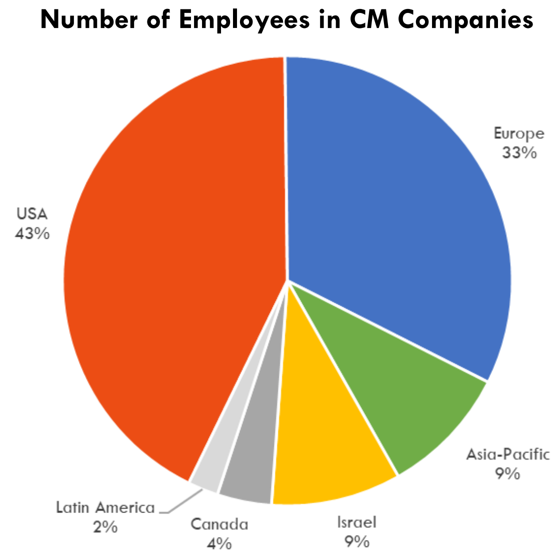

Figure 5-9: Employees in CM Start-ups by Region.
(For derivation of figure data, see Appendix G)

Next, as indication of the quality or professionalisation of CM start-ups by region, I looked at the investment received by CM companies in each region. I used data Crunchbase[19], an aggregator for company and investment information, see Appendix H for methodological notes. The industry received thus far $341 million according to this data. However, one investment over $161 million in the US-based CM start-up Memphis Meats[20] in January 2020 (GFI, 2020b) accounts for 47% of the total investments in CM alone. Before this investment, the investment received by region was roughly split 50:25:25 between the USA, Europe and Israel, see Figure 5-10.

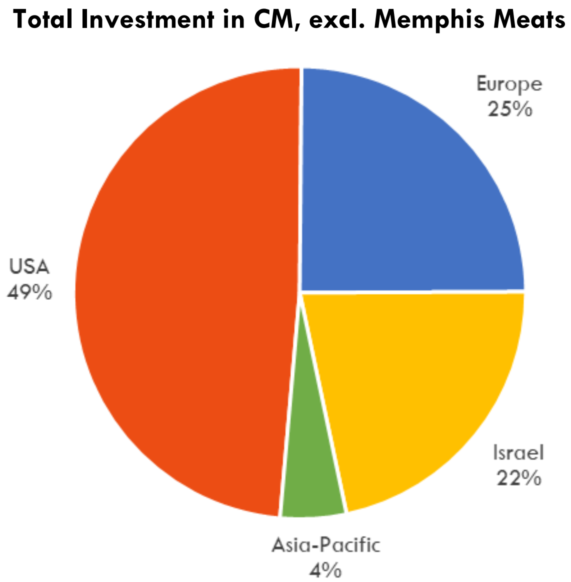

Figure 5-10: Investment in CM Start-ups by Region excluding Memphis Meats.
(For derivation of figure data, see Appendix H. Only investment above $1 mio.)

[19] Available online at: https://www.crunchbase.com/home; accessed 29/01/2020
[20] Webpage: https://www.memphismeats.com/; accessed 27/01/2020.

After this investment was made, however, the share shifted strongly towards the USA, see Figure 5-11. Now the investment share between the USA, Europe and Israel is approximately 80:10:10. In this split, the USA is with 76% of the investments ($259 million) clearly leading. Europe and Israel are roughly on pair, with 12% ($40 million) and 10% ($35 million) of the investments, respectively.

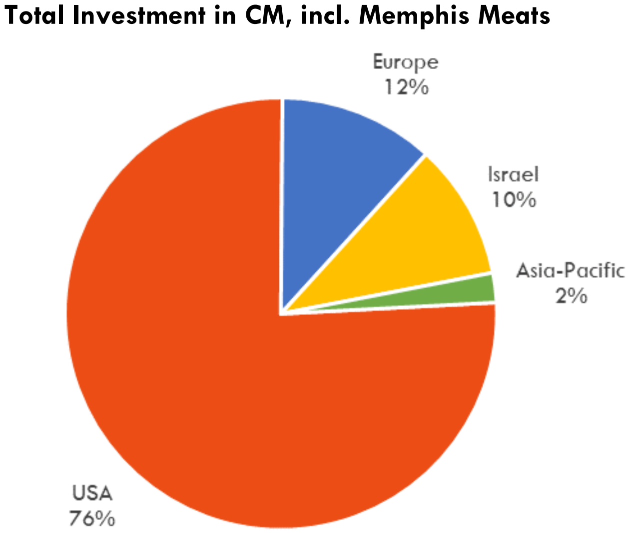

Figure 5-11: Investment in CM Start-ups by Region including Memphis Meats.
(For derivation of figure data, see Appendix H. Only investment above $1 mio.)

The combination of the figures so far – almost an equal number of start-ups in the USA and Europe, but substantially higher total investment in the USA, compare Figure 5-8 and Figure 5-10 respectively Figure 5-11 - indicates that there is a relative difference in investment per company by region.

Indeed, this is supported by the data, too, see Figure 5-12. Interestingly, excluding Memphis Meats, Israel is with an average investment of $12 mio. per funded CM company leading compared to the USA with 10$ mio. and Europe with $8 mio.

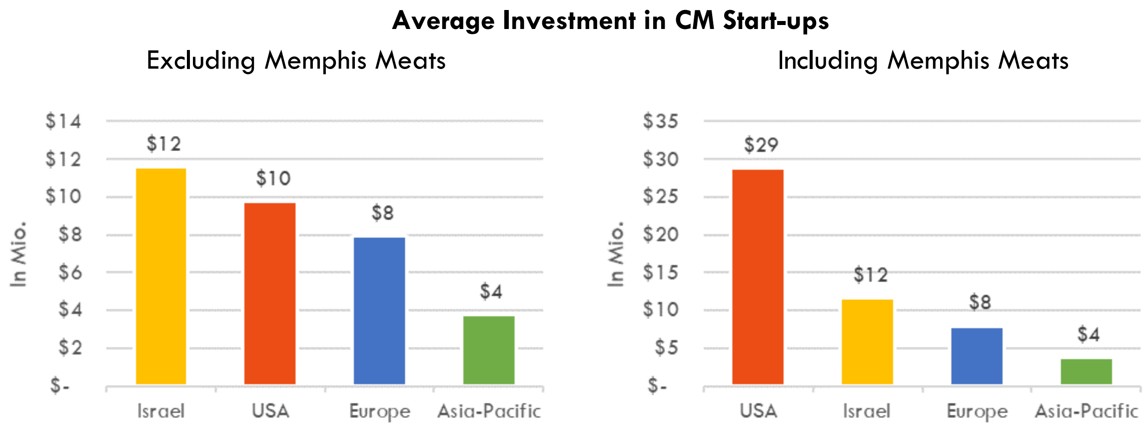

Figure 5-12: Average Investment per CM Company by Region.
(For derivation of figure data, see Appendix H. Only investment above $1 mio.)

This picture is further complemented when looking at what share of CM companies in each region received investment, see Figure 5-13. This data indicates a clear advantage of Israel over the USA and Europe. Surprisingly, based on this metric, the average European CM start-up is not substantially more professionalised than a CM start-up in the Asia-Pacific region.

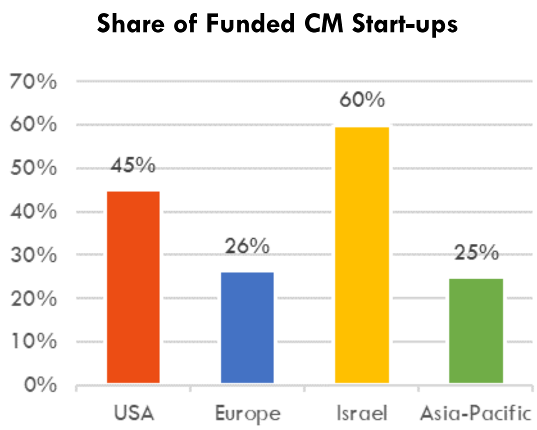

Figure 5-13: Share of Funded CM Start-ups by Region.
(For derivation of figure data, see Appendix H. Only investment above $1 mio.)

As further complementation, I looked at the average number of employees per CM start-up in each region, see Figure 5-14. The data indicates a comparable size of companies in the USA, Europe and Israel.

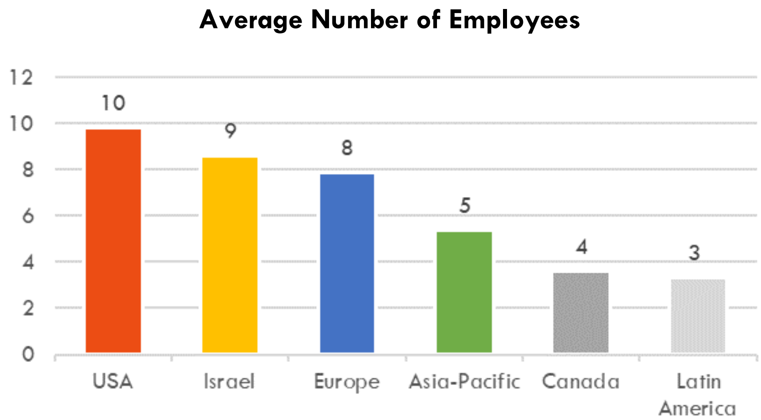

Figure 5-14: Average Number of Employees per CM Company by Region.
(For derivation of figure data, see Appendix G)

Lastly, I looked at the supply chain role the CM companies fulfil, see Figure 5-15. The difference is drawn between *focal* companies, 'platform' or 'brand' CM company that seeks to develop CM as main producer, and *supplier* companies, which focus on partial upstream aspects of the CM supply chain, such as bioreactor design. The difference between focal and supplier companies is a conventional differentiation in supply chain management (e.g. Frostenson & Prenkert, 2015). Based on the data presented, no major inference can be drawn. The split between focal and supplier companies is approximately equal between the USA and Europe: about 2:1 for focal to supplier firms. Nonetheless, Israel and the Asia-Pacific regions stand out with an over proportional share of focal companies.

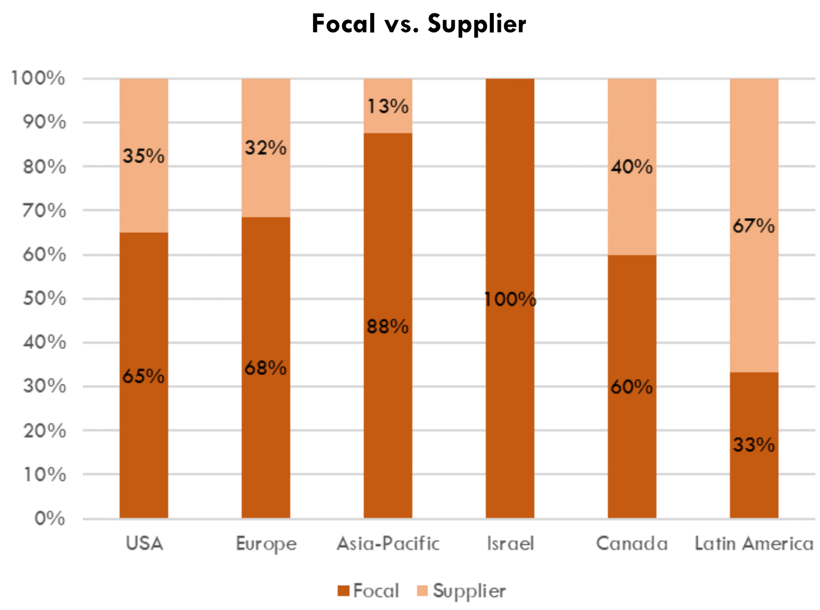

Figure 5-15: Split of Focal vs. Supplier Firms by Region.
(For derivation of figure data, see Appendix I)

Although it is not a main research question, I found it relevant to explore why the US start-ups received more funding than Europe's. Two possible explanations are timing (maybe US start-ups started earlier) and funding availability (maybe US start-ups have easier access to investment). Funding availability is evaluated in section 5.3.1, and timing in the next paragraph.

To evaluate whether timing played a role, I plotted the data on US and European CM start-ups from above against their founding year, see Figure 5-16[21]. The figure indicates that (a) start-ups in the US started substantially earlier, and (b) that only very recently – 2019 – the gap between both regions was compensated. In summary, this data appears to indicate that the gap in funding between both regions may be due to timing. Yet, inferences based on descriptive data alone are problematic.

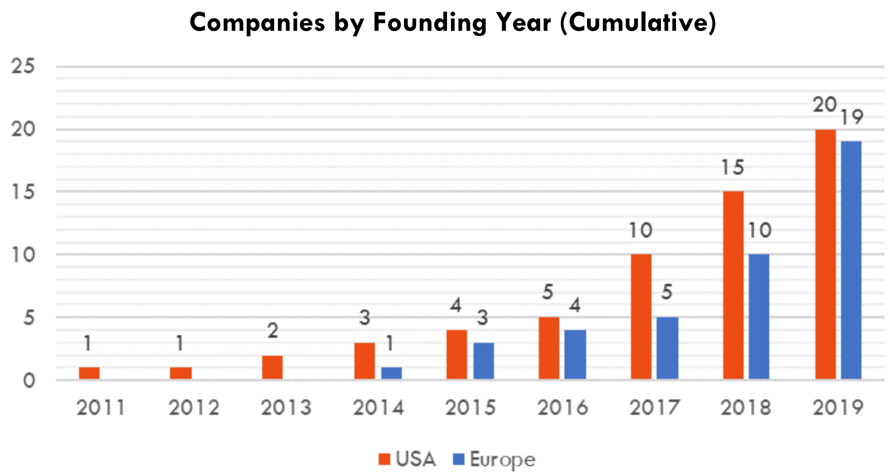

Figure 5-16: Cumulated Number of CM Start-Ups by Founding Year.
(With data from GFI, 2019c, 2019a)

Having explored the available quantitative data on entrepreneurial activity, I summarise subsequently the results of the interviews in this regard.

[21] This figure is similar to number of active companies in a given year. However, it does not consider if companies go inactive.

Interviews

From the interviews that I have conducted, two themes with relevance to entrepreneurial activity emerged. All interviewees who commented on this topic were obviously aware that there are a higher number of 'serious' CM start-ups in the USA – this information was taken as granted. The themes that evolved from the interviews are thus more explorative in nature, and for instance discuss causation behind this difference. Please see Table 5-8 for the entire list of quotes relevant to the theme.

The first theme that evolved is, linked to the question of why US start-ups received more funding**:** *the difference of the state of entrepreneurial activity is explained by timing, not team quality*. These following two quotes illustrate this theme:

> Interviewee 10 (NGO employee): *[The difference between US and Europe] "[is] just time. Most of them [start-ups in Europe] started just a few months ago. It just takes time to build, to find the team, prepare your pitch, contact investors"*, quote #2, Table 5-8

> Interviewee 15 (NGO employee): *"In terms of region … I don't know whether I've seen a difference in the quality of teams across regions."*, quote #3, Table 5-8

This implies that there is no 'external' reason why there is not more CM activity in Europe (such as worse teams, etc.), but simply timing.

The second theme in relation to entrepreneurial activity was: *the growth in number of CM start-ups was non-linear and is expected to continue.*

> Interviewee 9 (researcher): *"If we went back, let's say five years ago, it was not even a topic of conversation. It wasn't even in people's, you know, cerebral cortex at all. It was more a fantasy of science fiction movies and books."*, quote #5, Table 5-8

Table 5-8: Themes Entrepreneurial Activity.

Theme	Quotes	#
1: The difference of the state of entrepreneurial activity is explained by timing, not team quality	Interviewee 10 (NGO employee): *"In the US they have more start-ups, some of them appear more advanced. We have more early stage projects and start-ups in Europe."* [06:35]	1
	Interviewee 10 (NGO employee): *[The difference between US and Europe] "[is] just time. Most of them [start-ups in Europe] started just a few months ago. It just takes time to build, to find the team, prepare your pitch, contact investors"* [13:30]	2
	Interviewee 15 (NGO employee): *"In terms of region … I don't know whether I've seen a difference in the quality of teams across regions."* [05:57]	3
	Interviewee 7 (journalist): *"First I would say that there is [entrepreneurial] activity in very few countries. (…) I believe Germany is just the general average (…) in many countries nothing has happened yet."* [24:08]	4
2: The growth in number of CM start-ups was non-linear and is expected to continue	Interviewee 9 (researcher): *"If we went back, let's say five years ago, it was not even a topic of conversation. It wasn't even in people's, you know, cerebral cortex at all. It was more a fantasy of science fiction movies and books."* [00:29]	5
	Interviewee 16 (journalist): *"We're kind of in this next phase. (…) I think by next time this year, we're probably gonna have 140 different companies (…) Double the number of companies that we have now working on cultured meat.* [40:59]	6
	Interviewee 1 (investor): *"I believe in 2011, maybe 2013, the first cultured meat company was established and then it went to 60. So, in a period of now six years. That's how quickly the industry is growing. So, without a doubt, it's hard for a reporter or journalist to fully appreciate what's happening."* [02:12]	7
	Interviewee 16 (journalist): *"I also wouldn't be surprised to see that as soon as the regulation opens up (…) there will be a lot of announcements of either new companies coming out from stealth or incumbents in this space announcing that they have a cultured meat project now."* [40:59]	8

Having provided the content of the interviews, I subsequently evaluate the performance of entrepreneurial activity across regions.

5.2.2. Evaluation of Function Performance

How does the entrepreneurial activity in CM differ between the USA and Europe? The quantitative data I presented indicated: in terms of absolute numbers not substantially, but qualitatively, yes. The total number of start-ups in the USA is almost identical to those in Europe (Figure 5-8). The total number of employees is 31% higher in the USA, although the gap is not very high in absolute terms (USA: 196; Europe: 150) (Figure 5-9). The investment between both regions, however, differs substantially. US' start-ups received a total of $259 mio., Europe's merely $40 mio (Figure 5-11). Accordingly, US' start-ups received more investment on average than Europe's (Figure 5-12). Also, the share of CM start-ups that received funding in the US is 80% higher than in Europe (Figure 5-13). Lastly, the average number of employees per CM start-up is 25% higher in the USA than in Europe (Figure 5-14). However, the interviewees appeared to think that this difference is due simply to timing, a viewpoint the quantitative data on founding dates also invites (Figure 5-16). In summary, it seems that both regions are comparable in total entrepreneurial activity, albeit that US start-ups are larger and stronger funded, both potential indicators for professionalization and therefore start-up success. Overall, the entrepreneurial activity for CM appears to be clearly stronger in the USA than in Europe, see Table 5-9.

Table 5-9: Performance of Function 2: Entrepreneurial Activity.
(For ranking methodology, see section 3.3.2)

#	Function	Indicator	Measure	Comparison vs. Rest of the World		Comparison USA vs. Europe	
				USA	Europe	USA	Europe
2	Entrepreneurial activity		Number of CM companies	1st	2nd	Approximately on pair	
			Number of Employees	1st	2nd	USA leading (31% stronger)	Not leading
			Total investment	1st	2nd	USA leading (548% stronger)	Not leading
			Average Investment	1st	3rd	USA leading (263% stronger)	Not leading
			Share of Funded Start-ups	2nd	3rd	USA leading (73% stronger)	Not leading
			Average number of employees	1st	3rd	USA leading (25% stronger)	Not leading
			Team quality	Not compared		Approximately on pair*	
			Total average	1st	2nd / 3rd	USA leading	Not leading

* Based on qualitative data from the interviews.

Next, I present the results to the third function, resource mobilisation.

5.3. Function #3: Resource Mobilisation

5.3.1. Financial Capital: Venture Capital Availability

Desk-Research

What is the venture capital (VC) availability for CM in the USA and Europe? Overall, the investment in CM is growing heavily since 2015, see Figure 5-17[22]. Until the end of 2019, the industry received about

[22] The data used here is directly of the GFI (2019a, 2020) and differs slightly from that presented in section 5.2.

$155 million in total, with a compound annual growth rate of about 141% since 2015. As mentioned above, this was topped by a *single* investment in the US-based CM start-up Memphis Meats (GFI, 2020b). Although the now total investment of about $341 million appears big, one comparison: in the USA alone, the PBM and plant-based eggs and dairy industry received between 2009 and 2018 $17 *billion* in investments (GFI, 2019e). 2018 alone, the industry received $673 million (GFI, 2019e). Hence, although the investments in CM are growing very strongly, they are in total still minor in comparison to for instance the PBM industry.

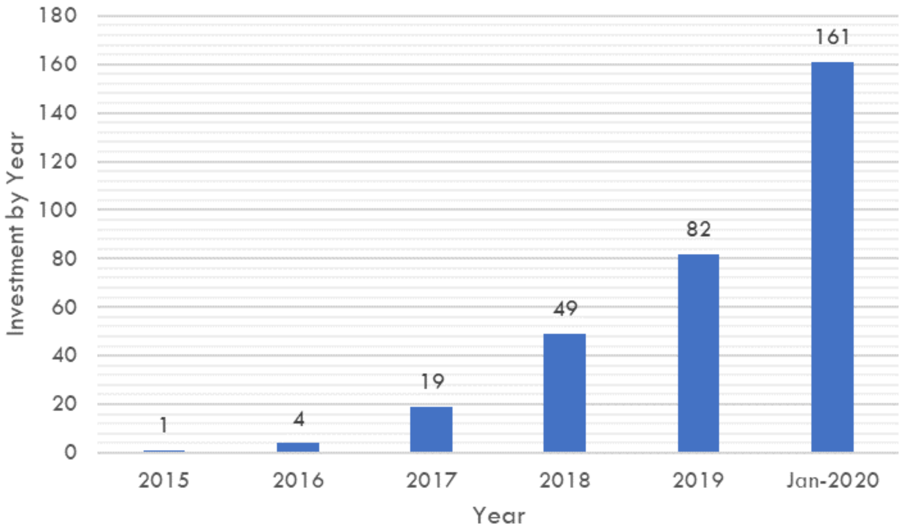

Figure 5-17: Capital Invested in CM per Year and Number of Deals.
(With data from GFI, 2019a, 2020b)

How does that translate into VC accessibility for a CM company between the USA and Europe? To the best of my knowledge, there is no quantitative data available to answer this question. Such a figure would need to explore, for instance, the probability of an identical firm located either in the USA or Europe to attract a given amount of money. Figures on where for instance VC firms are located give some correlational indication, but do not provide a causal answer.

To give some correlational indication: the VC industry is, generally-speaking, substantially larger in the USA than in Europe. The VC investments in per cent of GDP was between 2007 and 2015 in the USA 0.21% versus 0.03% in the EU (KfW, 2016). In other words: there was in the USA about six times more VC invested per unit of GDP than in Europe. One explanation for this difference, besides historical reasons, may be that VC is a more profitable business in the USA than in Europe: US' VC funds are approximately 50% more profitable than Europe's (Hege et al., 2009; Kumar, 2018). One explanation for the higher profits of VC funds in the USA is that an average exit[23] by an US' VC fund is worth approximately 180% more than that of a European VC firm (Basta, 2017). The reasons why exactly US' VC investments make more money is intricate, but it appears that one important reason is that the European market is more fragmented (Kumar, 2018). In other words: a successful US start-up can scale-up and sell to the large domestic US market, while a European start-up needs to adapt to every single new country in Europe.

How precisely the dominance of the US in the general VC industry translates to CM is not known: to the best of my knowledge, there is no exhaustive list of investors in CM that would allow a comparison. However, the data by the GFI (2019a) maps out some of the important investors. In total, 10 VC firms

[23] Exit is the act of selling shares (private equity) in a company for profit.

are mentioned that invested in at least more than one occasion in a CM company. Figure 5-18 below summarises the geographical location of these VC firms.

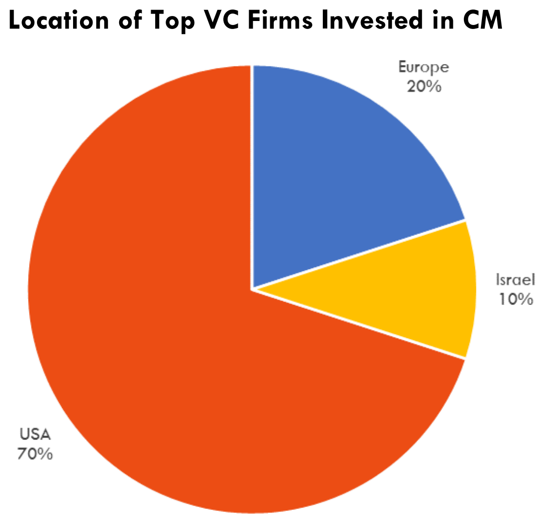

Figure 5-18: VC firm location with at least two investments in CM by region.
(For derivation of figure data, see Appendix J)

However, this data does not tell us whether a similar firm would have the same ease of attracting money in the USA versus in Europe. However, the interviews provided some information in this regard.

Interviews

With regards to VC availability two themes emerged, see Table 5-10. The first links directly to the evaluation of this functions' performance: *there is no scarcity in VC funding for good teams in the USA or Europe; only maybe early stage in Europe is missing*. There was a surprising consistency and clarity on this theme among interviewees.

> Interviewee 2 (investor): *"[If] you are a strong team, I don't think it's different [the funding situation between the USA and Europe]. [But if] you're not a really stand out team, I think it's difficult anywhere in the world."*, quote #1, Table 5-10

Coming back to the question raised in the previous section, why US' start-ups received more funding than European start-ups: the reason appears to thus not lay in funding availability, neither. Hence, it appears to be simply timing. I return to this issue in the discussion, see section 7.1.1.

The second theme related to the nature of investments that were put in the CM industry so far: *investments so far are mainly from strategic or impact investors*. Again, there was a strong consistency among interviewee's opinions on this issue.

> Interviewee 20 (investor): *"[For those investors] who really only look for financial return the risk is still problematic, it's problematic to be interested [in CM]. We can say that the most investors that we see are either impact driven, or they are some sort of strategic investors that hope to get stakes in a field that is potentially interesting for themselves in the future. Classical investors who only want financial returns would probably keep their fingers away from it yet."*, quote 8, Table 5-10

Table 5-10: Themes Financial Capital: Venture Capital Availability.

Theme	Quotes	#
1: There is no scarcity in VC funding for good teams in the USA or Europe; only maybe early stage in Europe is missing	Interviewee 2 (investor): *"[If] you are a strong team, I don't think it's different [the funding situation between the USA and Europe]. [If] you're not a really stand out team, I think it's difficult anywhere in the world."* [24:40]	1
	Interviewee 3 (entrepreneur): *[Whether attracting early stage, i.e. seed or pre-seed, investment for CM is difficult]: "Not really, no. I hasn't been difficult for us through active [business] angels investment, pre-seed and early stage investors."* [15:15]	2
	Interviewee 4 (entrepreneur): *"But nevertheless, finding money was relatively easy and it's actually been getting easier ever since to this day."* [17:19]	3
	Interviewee 4 (entrepreneur): *"What I would have liked is more financial support in the early stages from governments."* [26:13]	4
	Interviewee 10 (NGO employee): *[Whether attracting money in Europe is difficult]: "Don't think it's difficult at this moment. I do remember we have many investors interested [in investing in CM] for some months. I guess it is not the most difficult at this moment."* [14:29]	5
2: Investments so far are mainly from strategic or impact investors	Interviewee 1 (investor): *"Most VCs tend to be very focused on geography. Within the [CM] sector, we tend to be less focused [on geography] because we're more mission oriented."* [04:31]	6
	Interviewee 2 (investor): *"I would say the first wave of investors were mostly impact investors. And this is not to say impact investors can't be very sophisticated investors, but they have a different lens in terms of how they're making their decisions. (…) There wasn't even really [the] ability to do a lot of deep technical due diligence"* [11:28]	7
	Interviewee 20 (investor): *"[For those investors] who really only look for financial return the risk is still problematic, it's problematic to be interested [in CM]. We can say that the most investors that we see are either impact driven, or they are some sort of strategic investors that hope to get stakes in a field that is potentially interesting for themselves in the future. Classical investors who only want financial returns would probably keep their fingers away from it yet."* [10:52]	8

Next, I turn to the availability of research funding.

5.3.2. Financial Capital: Research Funding Availability

Desk-Research

What is the research funding availability for CM in the USA and Europe? To the best of my knowledge, there is no quantitative data on the funding availability for CM available. The organisation that appears to provide the most funding, particularly for PhDs, is the US-based NGO New Harvest[24]. I analysed who received their PhD scholarships. Although this information does not tell whether applicants in one geography were more likely to receive a scholarship, it does tell where funding is going. I found a total of 18 past PhD scholarships, for the geographical distribution see Figure 5-19.

[24] Accessible online at: https://www.new-harvest.org/; accessed 02/02/2020.

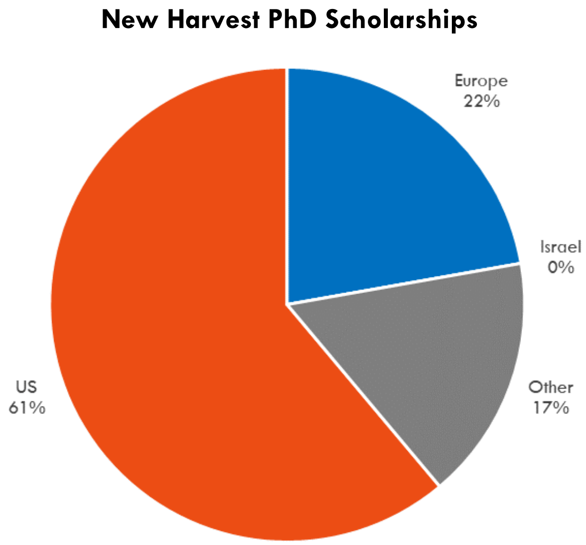

Figure 5-19: New Harvest PhD Scholarship Recipients by Region.
(For derivation of figure data, see Appendix K)

Since this was the only quantitative data, I could find on the research funding situation in CM, I turn to the interview results.

Interviews

The theme that involved for this function directly relates to the function evaluation, too: *there is currently insufficient research funding available in the USA and Europe*, see Table 5-11.

> Interviewee 9 (researcher): *"I will also add that even though progress is being made, it's still very difficult for academic labs, at least in the US (…) to have access to federal money [for CM research] (…) We're really tied mostly to non-profit organisations",* quote #3, Table 5-11

Overall, it appeared that interviewees took as granted that research funding is missing. It was almost not a point of discussion for that reason.

Table 5-11: Themes Financial Capital: Research Funding Availability.

Theme	Quotes	#
1: There is currently insufficient research funding available in the USA and Europe	Interviewee 5 (NGO employee): *"If all the public money is going towards other areas of biotech research, then that's where the labs will focus. (…) I think there needs to be a big shift in terms of publicly available funding. (…) There's loads and loads of really interesting [research] questions. But if you don't have the money to do the research, then it's not going to happen."* [22:09]	1
	Interviewee 21 (governmental official): *"I'd agree that it's important to finance basic research in the area (…) There are many different research funds available from governmental ministries. The problem is just to know who administers these funds."* [16:00]	2
	Interviewee 9 (researcher): *"I will also add that even though progress is being made, it's still very difficult for academic labs, at least in the US (…) to have access to federal money (…) We're really tied mostly to non-profit organisations"* [03:47]	3

Next, I turn to human capital.

5.3.3. Human Capital Availability

Desk-Research

How high is the availability of relevant human capital in the USA and Europe? I sought to quantify what is the raw availability of graduates relevant to CM companies. According to the OECD, an intergovernmental organisation, there were in 2017 about 8,000 PhD graduates in biological sciences and related sciences[25] in the USA, while there were about 13,000 in Europe (OECD, 2017). However, how does this translate into the quality of graduates? A rough estimation might be given by university rankings. To explore this, I used the QS subject ranking for biological and related sciences, which gives 50% of the weight to a publication analysis and 40% to academic reputation (QS, 2019). According to this ranking, of the top 100 universities in biological and related sciences, 22 are in the US, and only 8 in Europe. Based on these figures, one may argue that Europe is leading in terms of quantity of graduates, but the USA in terms of quality of graduates. Beyond these general figures, I did not find relevant information on the availability of CM-relevant potential employees. I thus turn to the interview results.

Interviews

Regarding the availability of human capital, two themes were observed, see Table 5-12. Firstly: *there is no scarcity in good employees or PhD students in USA or Europe*.

> Interviewee 4 (entrepreneur): *"It's not really the issue of finding people. We found (…) very good people (…) and hired them as well. (…) [And they are] completely up to our expectations or beyond that, not just on the scientific level, which is probably one of the aspects you need to measure, but also on their mission drive. It is really strong. It's almost a bit too strong in the sense that we need to keep an eye on people that they also have a private life.",* quote #2, Table 5-12

This theme appeared for both the USA and Europe, so apparently the human capital availability in both regions is fine. However, qualifying these results, the second theme showed a cross-regional difference: *there is difficulty finding scientist co-founder in Europe*.

> Interviewee 11 (researcher): *"[Regarding a scarcity of scientists to join start-ups in Europe:] So that is something I would definitely subscribe to, that is also the impression I get so far. Simply because there were already several people who approached us, people without a science background, mostly some businesspersons who see the market potential."*, quote #5, Table 5-12

Table 5-12: Themes Human Capital Availability.

Theme	Quotes	#
1: There is no scarcity in good employees or PhD students in USA or Europe	Interviewee 1 (investor): *"I would say that there's certainly a difference between the density of talent of [for instance] Kansas City, Wisconsin or Idaho from the Bay Area. But between San Francisco and let's say Amsterdam, I'm not sure that I would be able to draw that distinction"* [06:03]	1
	Interviewee 4 (entrepreneur): *"It's not really the issue of finding people. We found [blanked] very good people in [blanked] months and hired them as well. (…) [And they are] completely up to our expectations or beyond that, not just on the scientific level, which is probably one of the aspects you need to measure, but also on their mission drive. It is really strong. It's almost a bit too strong in the sense that we need to keep an eye on people that they also have a private life."* [17:19][26]	2
	Interviewee 9 (researcher): *"[The] most positive thing from this field is [that] there is no shortage of finding really smart, incredibly motivated graduates to work in this field (…) So, in terms of person power (…) – folks wanting to get involved – if I had more money, I would have a huge team because I have so many great candidates."* [11:01]	3
2: There is difficulty finding scientist co-founder in Europe	Interviewee 10 (NGO employee): *"I know that they [CM start-ups in Europe], most of them, are looking for a scientist to work with them and that's not easy to find. (…) I was talking with one of them and [he or she] said that some people prefer to work with big companies (…) because it's more secure for them and the salaries might be higher. (…) I mean we have enough regular founders – you know, businesspeople – but we are lacking scientists in Europe."* [32:48]	4
	Interviewee 11 (researcher): *"[About the scarcity of scientists to join start-ups in Europe] "So that is something I would definitely subscribe to, that is also the impression I get so far. Simply because there were already several people who approached us, people without a science background,*	5

[25] Biological sciences and related sciences were seen as the right category for CM, as it for instance includes relevant fields such as biotechnology and tissue engineering.
[26] To protect anonymity of the interviewee, certain parts of this quote were blanked.

mostly some businesspersons who see the market potential" [23:30]

Next, I explore the factor of physical capital and supportive infrastructure.

5.3.4. Physical Capital and Supportive Infrastructure Availability

Desk-Research

How strong is the availability of physical capital and supportive infrastructure in the USA and Europe? The data availability for CM-relevant physical capital and supportive infrastructure is also somehow limited. However, the GFI has created a map of incubators and accelerators in agricultural technology, biotechnology, and food technology (GFI, 2020a). Incubators are programs that help potential founders to start a company. For CM, they typically include required physical infrastructure, i.e. laboratories, and further support, for instance coaching. Accelerators are basically the next step. Accelerators help already existing start-ups to scale up their business.

Figure 5-20 shows the geographical distribution of CM-relevant incubators. Overall, there are 187 incubators recorded. For the USA, 162 (87%) are marked, for Europe merely 10 (5%). However, this data should be taken with a grain of salt, as the GFI (2020a) writes that the data for outside of the US might be not comprehensive. Despite this uncertainty, I suppose it is fair to argue that it is unlikely that any of the world's regions compared as has many CM-relevant incubators as does the USA.

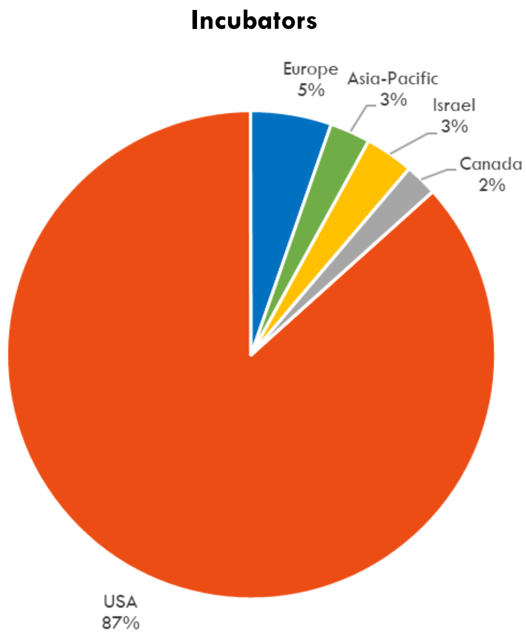

Figure 5-20: CM-Relevant Incubators by Region.
(With data from GFI, 2020a)

Figure 5-21 shows the geographical split of CM-relevant accelerators. On this metric, the picture appears more balanced: the USA and Europe both have the same number of accelerators, 31. Hence, on a later stage, there appears equal support available in the USA and Europe.

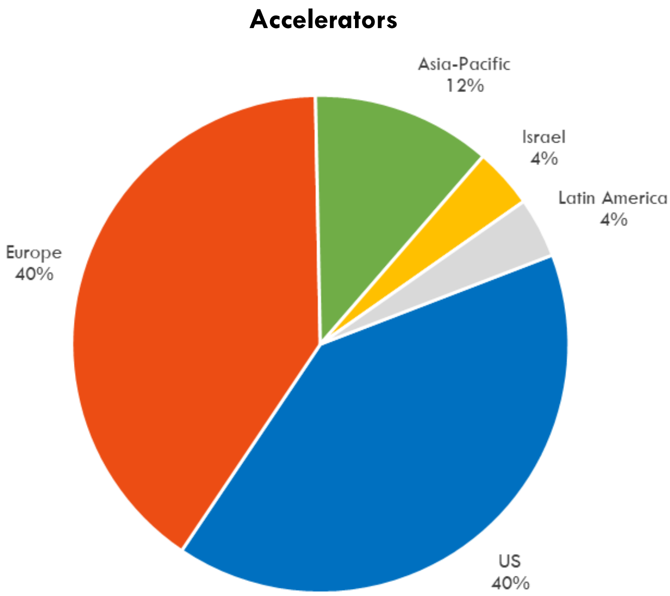

Figure 5-21: CM-Relevant Accelerators by Region.
(With data from GFI, 2020a)

Next, I discuss the interview results.

Interviews

With relevance to this function, one clear theme evolved: *in Europe it is not easy to get the required equipment, in the USA it is*, see Table 5-13.

> Interviewee 3 (entrepreneur): *"We're looking at setting up in San Francisco where those … there's a lot of that [available lab space]. Actually there's like an off the shelf kind-a (…) lab space where you can just do it month to month (…) That's one of the reasons that it's an attractive area."*, quote #1, Table 5-13

> Interviewee 10 (NGO employee): *"All of them [CM start-ups in Europe] need a place to do experiments and that's not very easy because they don't know how to proceed with that. (…) It would be great to have more accelerators or incubators with this special equipment, but it's quite expensive"*, quote #3, Table 5-13

This theme appears to confirm the results from the quantitative search, see Figure 5-20: that the US leading in this regard. However, a difference between incubators (very early stage support) and accelerators (growth support) could not be identified.

Table 5-13: Themes Physical Capital and Supportive Infrastructure.

Theme	Quotes	#
1: In Europe it is not easy to get the required equipment, in the USA it is	Interviewee 3 (entrepreneur): *"We're looking at setting up in San Francisco where those … there's a lot of that [available lab space]. Actually there's like an off the shelf kind-a (…) lab space where you can just do it month to month (…) That's one of the reasons that it's an attractive area."* [10:58]	1
	Interviewee 4 (entrepreneur): *[Direct quote not possible to preserve anonymity. But he or she said that it is difficult to get lab space in Europe unless you get it from a university.]*	2
	Interviewee 10 (NGO employee): *"All of them [CM start-ups in Europe] need a place to do experiments and that's not very easy because they don't know how to proceed with that. (…) It would be great to have more accelerators or incubators with this special equipment, but it's quite expensive"* [19:21]	3
	Interviewee 15 (NGO employee): *"There's a lot of incubators and accelerators in California, and that could be another reason why we've had a lot kind of early successes for cultivated meat there."*	4

Having explored all of this functions' indicators, I move next to the evaluation of the function performance.

5.3.5. Evaluation of Function Performance

How does the resource mobilisation differ between the USA and Europe? Firstly, VC availability. Generally-speaking, there is about six times more VC available per unit of GDP in the USA than in Europe. Though, it is not clear how this translates to CM funding availability. Based on the interviews, it appears that the accessibility to funding for CM start-ups is similar in both regions, given a start-up team is of same quality. However, there are more CM-focused VCs present in the USA (Figure 5-18). Secondly, research funding availability. Here the situation appears again to be equal between both regions; in this case, equally bad. However, the USA is clearly leading when it comes to CM-relevant PhD scholarships (Figure 5-19). Thirdly, human capital availability. For this indicator Europe appears to be leading in terms of quantity of relevant graduates and the USA in terms of quality of relevant graduates. In terms of accessibility of applicants, interviewees noted more than enough good applicants in both regions. However, in Europe there appears to be a shortage in scientist co-founders, the interviews indicated. Lastly, physical capital and supportive infrastructure. On this metric, the USA appears to be leading. The USA has more incubators than Europe (Figure 5-20), although it is not sure how many more exactly. For accelerators, both regions have exactly the same number (Figure 5-21). However, the interviewees noted that in terms of accessibility of labs on an early stage, the USA is leading. This is likely relatable to the difference in incubators between both regions. Overall it appears that on average the resource mobilisation for CM is stronger in the USA than in Europe, see Table 5-14.

Table 5-14: Performance of Function 3: Resource Mobilisation.
(For ranking methodology, see section 3.3.2)

#	Function	Indicator	Measure	Comparison vs. Rest of the World		Comparison USA vs. Europe	
				USA	Europe	USA	Europe
		Financial Capital: Venture Capital Availability	VC availability per unit of GDP	Not compared		USA leading (600% stronger)	Not leading
			Accessibility to VC capital	Not compared		Approximately on pair*	
			Local presence of CM-relevant VC firms	1st	2nd	USA leading (250% stronger)	Not leading
		Financial Capital: Research Funding Availability	Accessibility to research funding	Not compared		Approximately on pair*	
			Recipients of PhD scholarships	1st	2nd	USA leading (177% stronger)	Not leading
3	Resource Mobilisation	Human Capital Availability	Number of relevant graduates	Not compared		Not leading	Europe leading (63%)
			Quality of graduates	Not compared		USA leading (175% stronger)	Not leading
			Accessibility to applicants	Not compared		Approximately on pair*	
			Scientist co-founder	Not compared		USA leading*	Not leading*
		Physical Capital and Supportive Infrastructure Availability	Number of incubators (early stage support)	1st	2nd / 3rd / 4th	USA leading (1640% stronger)[1]	Not leading
			Number of accelerators (growth support)	1st / 2nd	1st / 2nd	Exactly on pair	

	Access to early stage labs	Not compared		USA leading*	Not leading*
	Total average	1st	2nd	USA leading	Not leading

* Based on qualitative data from the interviews.
[1] In reality advantage likely lower, yet still existent.

Next, I turn to the 4th function, positive externalities.

5.4. Function #4: Positive Externalities

5.4.1. Entrepreneurial Ecosystem Strength

Desk-Research

How strong is the entrepreneurial ecosystem in the USA and Europe? To evaluate this question, I looked at two measures. The first is the total VC investment start-ups received in top 50 cities[27], a measure for start-up activity by location.

Figure 5-21 maps the geographical distribution of the frequency of top 50 start-up cities. As one can see, the USA hosts with 42% the highest number of leading start-up cities, and then the Asia-Pacific region with 30%. Europe comes on a 3rd place, with 16%. The list includes cities one would have expected: for the USA, for instance, San Francisco, New York, or Boston; for Asia-Pacific Beijing, Shanghai, or Bangalore; and for Europe London, Berlin, or Paris. Israel has with Tel Aviv just one city in the top 50. The relative advantage of the USA over Europe is 163% on this measure.

Top 50 Leading Start-Up Cities

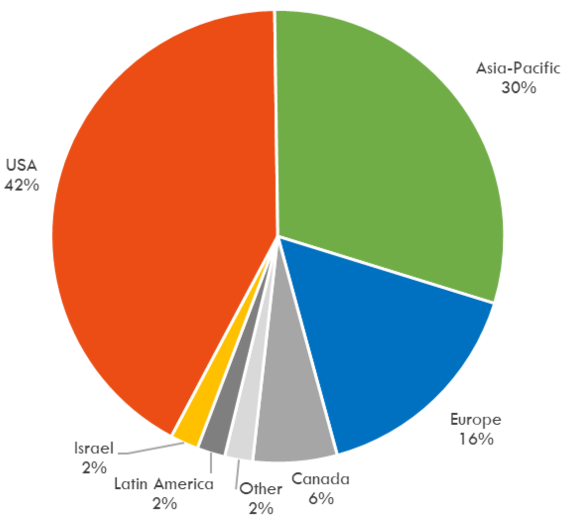

Figure 5-22: Top 50 Leading Start-up Cities by Region.
(With data from Florida & Hathaway, 2018)

How does this measure translate to CM? I looked at what share of CM start-ups are located in a top 50 start-up city. I assume that start-ups located in such a city will likely benefit from positive externalities, which is what the literature on start-up clusters suggests (Avnimelech et al., 2008; Joshi, 2018; Lee, 2018).

[27] Note that I use this measure not as an indication of VC availability ("supply side"), but where most promising start-ups are located ("demand side"). Applying the reverse logic would also be possible, but I suppose, less granted.

Figure 5-23 shows the share of CM start-ups located in top 50 start-up cities by region. This data indicates that the USA is clearly leading and Asia-Pacific coming second. Europe is coming fourth. Translated this data would indicate that, for instance, an US-American CM start-up is likely to benefit from stronger positive externalities than an average European start-up. However, one should add that this view only considers 'macro' positive externalities from the CM-unspecific entrepreneurial ecosystem, not those derived from more direct network benefits, such as being supported by a biotechnology accelerator.

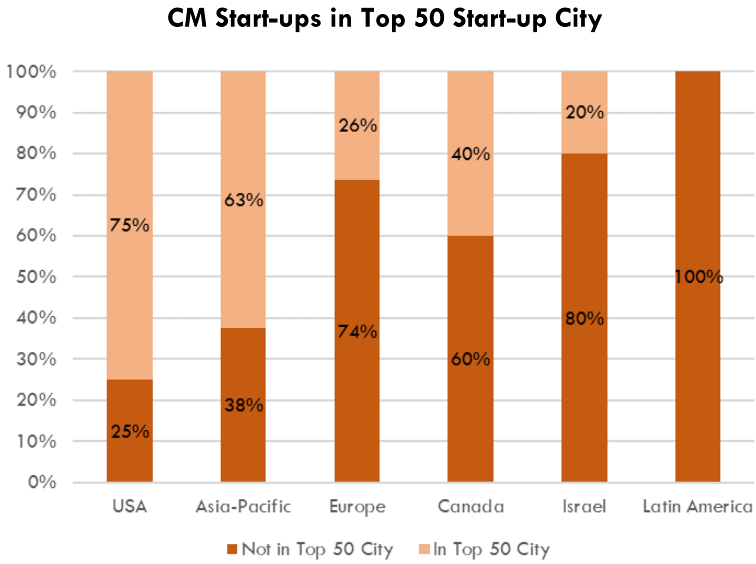

Figure 5-23: Share of CM Start-ups in Top 50 Start-up City by Region.
(Crossing of data of Appendix F with Florida & Hathaway, 2018)

In addition, I looked at the Global Entrepreneurship Index (GEDI, 2017). This index is a measure of entrepreneurial ecosystems. The index measures 14 so-called pillars, composite ratings of institutional variables and individual variables. The 14 pillars are clustered in three themes: entrepreneurial attitudes, entrepreneurial abilities and entrepreneurial aspirations. One example: one pillar is start-ups skills; the responding institutional variable is tertiary education and the responding individual variable skill perception. In other words: are people trained (institution) and do they think they are trained (individual)? Hence, the index measures in total 28 variables (14 times two).

On a scale from 0 to 1, with 0 low and 1 high, the USA has a rating of 0.84, Europe 0.58[28], and Israel 0.65 (GEDI, 2017)[29]. Based on this big picture comparison, the USA appears to be leading, followed by Israel, and followed by Europe. However, on a detail, some leading European countries perform differently: the Netherlands has a rating of 0.68, Germany 0.66, France 0.69, and the United Kingdom 0.78; the four countries average is 0.70. In other words, adjusted for the countries focused on in this thesis, see section 0, the USA is leading, with Europe coming second, and Israel third. The relative advantage of the USA over Europe is 20%, indicating that there is an advantage for the USA, but not very substantially.

Having explored the available quantitative data on the strength of the entrepreneurial ecosystems, I subsequently present the interview results.

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[28] Weighted average of countries that are part of the European Union, European Free Trade Association and the United Kingdom. Weighting by population size.

[29] I did not extend the comparison to other world regions out of time constraints.

Interviews

The interviews indicated one theme: *the entrepreneurial ecosystem is stronger in the USA than in Europe, but unclear whether it matters*, see Table 5-15.

> Interviewee 20 (investor): *"There are certain advantages when one is in some sort of cluster, but there is not yet such a conglomeration (of CM companies] that this yields big synergies"*, quote #5, Table 5-15

Table 5-15Firstly, all interviewees explicitly or implicitly suggested that the entrepreneurial ecosystem is stronger in the USA, particularly in the Bay Area. These results mirrors that of the quantitative section.

> Interviewee 10 (NGO employee): *„(…) everything is happening faster in the US. Because they already have everything there. They have the equipment, they have the investors, they have the people with the mindset of being entrepreneurs. It's just easier."*, quote #4, Table 5-15

However, some doubted whether this advantage necessarily matter; or indicated that it may only matter in certain situations.

> Interviewee 20 (investor): *"There are certain advantages when one is in some sort of cluster, but there is not yet such a conglomeration (of CM companies] that this yields big synergies"*, quote #5, Table 5-15

Table 5-15: Themes Entrepreneurial Ecosystem Strength.

Theme	Quotes	#
1: The Entrepreneurial ecosystem is stronger in the USA than in Europe, but unclear whether it matters	Interviewee 2 (investor): *"It's a complex question [whether it is beneficial for a CM start-up to be located in a certain geography] because there are so many different dimensions to it. There's a team [that] left Asia, [and] decided to join Y combinator [an accelerator] in the US (…) There are different decision criteria, right? Where can I hire talent, where can I secure the right funding? Where can I have the ecosystem to support what I need? There's also the counter argument: do I go into [the] ecosystem that's more mature [but] has more competition? But [if] I don't have a strong differentiating angle or unique advantage, maybe it doesn't make sense [to be in a strong ecosystem] because there are already too many teams there."* [18:10]	1
	Interviewee 2 (investor): *"When we say Europe – there's only a few (…) meaningful start-up hubs, right? It gets harder starting a cultivated meat company in a small town in Portugal compared to Berlin, for example. (…) If you're the first [in a sense of first mover, a strong advantage] and you [have] a strong team – I don't think it's different [where you are located]."* [22:44]	2
	Interviewee 10 (NGO employee): *„I think that most of the start-ups are in California, in San Francisco – in the US – makes it easier for them. (…) To network with each other, to share equipment, maybe to share knowledge. And in Europe the start-ups, the projects are all over the place in Europe. I think it makes it more difficult."* [06:39]	3
	Interviewee 10 (NGO employee): *„(…) everything is happening faster in the US. Because they already have everything there. They have the equipment, they have the investors, they have the people with the mindset of being entrepreneurs. It's just easier."* [20:27]	4
	Interviewee 20 (investor): *"There are certain advantages when one is in some sort of cluster, but there is not yet such a conglomeration (of CM companies] that this yields big synergies"* [18:10]	5
	Interviewee 15 (NGO employee): *"Yeah, it's just culturally. There is definitely more people leaving companies in California to go working for other companies in that [i.e. people shifting among CM companies]. Helps [to] reduce the amount of siloing that's happening in the industry. You know, technically they're not supposed to take the IP [intellectual property] that they developed at (…) their previous company to the new company, but I imagine it's still at least some of that knowledge gets transferred. I think one of the great things about the Silicon Valley is [that] there's a different perception of risk or failure. Failure is not really viewed negatively. And neither is taking big risks. So I think people feel more comfortable going to work for an unproven industry like cultivated meat."* [06:24]	6

The next section explores the sector strength.

5.4.2. Biotechnology Sector Strength

Desk-Research

How strong is the biotechnology sector, to which CM can be attributed from a technological standpoint, in the USA versus Europe?

In general terms, the biotechnology sector is more fragmented in Europe, but in terms of revenue substantially larger in the USA. Between 2014 and 2016, an average of 2,884 biotechnology firms were counted active in the USA, versus 8,312 in Europe (OECD, 2018). On first glance, this may mean that Europe's biotechnology is 'larger' than that of the USA. However, it appears that Europe's biotechnology sector is rather more fragmented, as three data points indicate. Firstly, revenue. Again between 2014 and 2016, the US' biotechnology sector had an average annual revenue of $104 billion, while Europe's had merely an average annual revenue of $25 billion (EY, 2017). In other words: the US' biotechnology sector is 316% the size of Europe's. Secondly, top enterprises. Of the 10 largest biotechnology companies, six are US-American, and only three European (Financial Times, 2019). Hence, on this measure the US has a 100% advantage. Lastly, of the top 8 biotechnology clusters, the USA hosts six, Europe just one (EY, 2017). Overall, one can thus argue that the biotechnology sector is stronger in the USA than in Europe.

Next, I explore the interview results to this issue.

Interviews

Similar to the interview results of the last section, the theme that evolved is: *the biotechnology sector is stronger in the USA compared to Europe*, see Table 5-16.

> Interviewee 17 (supplier employee): *"I can only speak for culture media, and maybe also bioreactors. For these they are very well positioned in the USA. In Europe, the established suppliers are rare. There are rather the American international companies that are specialised in this sector, for instance Thermo Fisher. (…) But I think small, specialised suppliers – those without huge revenues – are rather located in Europe or Israel than in the USA."*, quote #1, Table 5-16

However, I suppose the same claim as for last section can be made: it is unclear whether it matters that the biotechnology sector is stronger in the USA.

Table 5-16: Themes Biotechnology Sector Strength.

Theme	Quotes	#
1: The biotechnology sector is stronger in the USA compared to Europe	Interviewee 17 (supplier employee): *"I can only speak for culture media, and maybe also bioreactors. For these they are very well positioned in the USA. In Europe, the established suppliers are rare. There are rather the American international companies that are specialised in this sector, for instance Thermo Fisher. (…) But I think small, specialised suppliers – those without huge revenues – are rather located in Europe or Israel than in the USA."* [44:42]	1
	Interviewee 1 (investor): *"I understand that there's a San Francisco based tax incentive for biotech companies in San Francisco."* [07:43]	2
	Interviewee 5 (NGO employee): *"I think that those branded companies [focal CM companies] are located there [in hotspots like the Bay Area] for a couple of reasons, right? There's technical expertise from either the biomedical industry or universities that are focused on biomedicine in those hotspots. But also, there's a thriving and interested investment community (…) And I think if a company is dedicated to creating a technology to support those branded companies, it's probably going to be easier for them to start in those regional hot spots."* [11:20]	3

Next, I come to the evaluation of this function's performance.

5.4.3. Evaluation of Function Performance

How do the positive externalities acting on the CM industry differ between both regions? Firstly, the strength of the entrepreneurial ecosystem. The USA hosts more top 50 start-up cities (Figure 5-22) and a higher share of US' firms are located in such a city (Figure 5-23). Likewise, the performance of the USA in the global entrepreneurship ranking is higher, and interviewees interpreted the ecosystem to be stronger than Europe's. A similar picture emerged for the biotechnology sector strength. US' biotechnology firms have a higher total revenue and the region has a higher share of the top 10 biotechnology firms. Moreover, the USA has a higher share of top worldwide biotechnology clusters and interviewees confirmed that they perceive the US' biotechnology sector to be stronger than Europe's. Overall it appears that the IS for CM in the US offers stronger positive externalities than Europe's, see Table 5-17.

Table 5-17: Performance of Function 4: Positive Externalities.
(For ranking methodology, see section 3.3.2)

#	Function	Indicator	Measure	Comparison vs. Rest of the World		Comparison USA vs. Europe	
				USA	Europe	USA	Europe
4	Positive Externalities	Entrepreneurial Ecosystem Strength	Frequency of top 50 start-up cities	1st	3rd	USA leading (163%)	Not leading
			Share of CM start-ups in top 50 cities	1st	4th	USA leading (188%)	Not leading
			Performance in Global Entrepreneurship Ranking[1]	Not compared		USA leading (20%)	Not leading
			Overall ecosystem strength	Not compared		USA leading*	Not leading*
		Biotechnology Sector Strength	Total Revenue of Biotechnology Firms in Region	Not compared		USA leading (316%)	Not leading
			Share of 10 largest biotechnology firms	Not compared		USA leading (100%)	Not leading
			Share of top 8 biotechnology clusters	1st	2nd / 3rd / 4th	USA leading (500%)	Not leading
			Overall biotechnology sector strength	Not compared		USA leading*	Not leading*
		Total average		1st	3rd / 4th	USA leading	Not leading

* Based on qualitative data from the interviews.
[1] Based only on the Netherlands, Germany, France, and the United Kingdom.

Next, I explore the function legitimation.

5.5. Function #5: Legitimation

5.5.1. Lobbying Activity

Desk-Research

Is there lobbying activity for and against CM happening? To the best of my knowledge, the lobbying activity in favour or against CM cannot be analysed quantitatively. Accordingly, I subsequently discuss available information points instead. See the actor analysis, Table 4-1, for an overview of the actors mentioned in this section.

There exists anti-CM lobbying in the USA and in Europe, in both regions driven by meat producers. Anti-CM lobbying began in the US already 2018 (Stephens et al., 2019). The National Cattlemen's Beef Association, for instance, filed a petition to the USDA that CM products may not be called "meat" (Shapiro, 2018). Until the end of 2019, over 30 US states have or are considering to prevent CM to be called "meat", and preventive laws were passed in 12 states (Corbyn, 2020). Yet, federal legislation subsumes state legislation, so it is not granted how CM will be eventually allowed to be named in these states. In Europe, the anti-CM lobbying is more in the public sphere and appears more limited in scope. The anti-CM lobby started a campaign called "Meat the Facts" by an organisation called "European Livestock Voice"[30], which unites many national meat lobby groups. The campaign contrasts conventional meat to CM, trying to work out the advantages of the former and the disadvantages of the latter. The campaign displayed photos in underground train stations in Brussels, the seat of most of EU's executive organs, arguably wanting to influence policymakers. For a example of the campaign, see Figure 5-24. However, despite this public display, there was no effect on policymaking in Europe yet comparable to that in the USA to my knowledge.

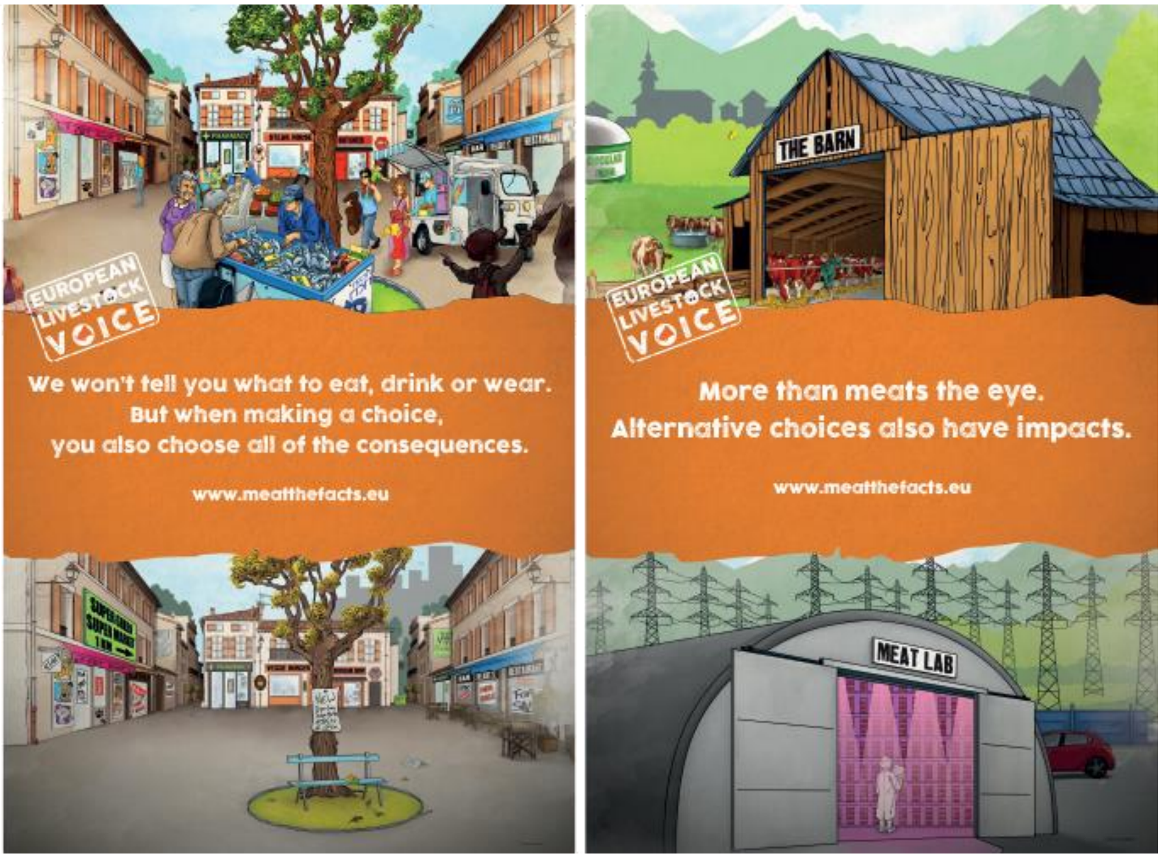

Figure 5-24: Example of Anti-CM Lobbying Campaign in Europe.
(Adapted after European Livestock Voice, 2019)

Who supports the anti-CM lobbying? It appears that the reaction of incumbent meat companies follows their company size. Some large, corporate meat producers appear to embrace CM. For instance, Tyson Foods and Cargill Meat Solutions, number two and three of the largest US' meat producers (NP, 2018), both invested in CM; Tyson Foods in the US' start-up Memphis Meats (Tyson Foods, 2018) and Cargill in the Israeli start-up Aleph Farms (Cargill, 2019), among other CM-related investments. In addition to their investment in CM, the meat producers also heavily invest in PBM (Yaffe-Bellany, 2019). Likewise, the PHW Group, one of the largest meat producers in Europe, invested in the Israeli start-up SuperMeat (Michail, 2018). Overall, it appears that US' meat producers are

[30] Available online at: https://meatthefacts.eu/; accessed 06/02/2020.

embracing CM slightly more, given that there are less investments in CM known from European meat producers. Yet, one should note that despite these investments, probably still a majority of large meat producers remains passive towards CM. In comparison to this embracing behaviour, the reaction of small-scale meat producers is the contrary. The anti-CM lobby activities described above were largely organised by associations that unite the interest of small-scale meat producers. Such a behaviour could be interpreted to not come as a surprise, because an industry as CM – capital and research intense as it is – is unlikely to be a potential new business for small-scale farmers. Hence: while cross-regionally some large meat producers appear to embrace CM, small-scale producers appear to oppose it, while most remain arguably in a waiting stance, independent of size.

Pro-CM lobbying exists also in the USA and in Europe, albeit less explicit. In the USA, the GFI is lobbying at least since 2016 for CM (Purdy, 2016). It was the counter actor to the activities started by the US' meat lobby, as discussed above. In August 2019, the US' CM industry created their own interest group, the "Alliance for Meat, Poultry & Seafood Innovation"[31] that aims at promoting CM. Their first five member companies are Memphis Meats, Finless Foods, BlueNalu, JUST, and Fork and Goode (Banis, 2019). In Europe, the pro-CM lobbying is more limited. The GFI expanded in 2019 to Europe and has, state August 2019, only two lobbyists registered at the EU (LobbyFacts, 2019). Yet, as comparison, the GFI counts a total of 60 employee at the point of writing[32], so the European office is very small in comparison. Aside the GFI, the pro CM lobbying in Europe appears limited. On a European level, the German vegetarian association, ProVeg International, is actively engaged in CM[33], for instance with their own incubator. On a national level, I could find only on industry interest group, the "Association for Alternative Protein Sources" (in German: *Verband für Alternative Proteinquellen*)[34], which unites companies in the broader meat alternatives and cellular agriculture space. However, I could find no information on lobby activities organised by the association and it does not entail any funded CM company. Overall, it appears that anti-CM *and* pro-CM lobbying is stronger in the USA than in Europe, equalling the effect out for both regions. Yet, it appears that CM interest groups are better developed in the USA.

I subsequently turn to the results of the interviews regarding this function.

Interviews

In the interviewees, no significant theme emerged regarding lobbying activity. The topic appears hard to track or get an educated opinion on, which may lay in the nature of lobbyin. During data collection, interview requests to individuals who are engaged in CM-related lobbying activities were made, but those requests were rejected. However, there was one interesting observation by one interviewee regarding large, incumbent meat producers:

> Interviewee 4 (entrepreneur): *"We talked to the meat industry. They are very aware that they will have to change in the next decades. They just don't know exactly how to do so. Strange enough they are quite receptive for technologies like these, but they consider them to coexist with what they do, not so much that they replace what they do."* [30:18]

Hence, it appears that incumbent companies are aware that things need to change. Next, I discuss the reaction by the civil society.

[31] Accessible online at: https://ampsinnovation.org/; accessed 06/02/2020.
[32] Accessible online at: https://www.gfi.org/our-team; accessed 06/02/2020.
[33] Accessible online at: https://proveg.com/; accessed 06/02/2020.
[34] Accessible online at: https://balpro.de/; accessed 06/02/2020.

5.5.2. Reaction by the Civil Society

Desk-Research

What is the reaction towards CM by the civil society? As reminder, I defined the civil society as 'third sector' in addition to businesses and governments (Ehrenberg, 2017; L. Lewis, 2005). There is only limited objective information on the public reception of CM available. In terms of existing research, merely one publication noted that the media representation of CM in Western countries is over proportionally constituted by vegetarian's reactions to it (Hopkins, 2015). Additional indication might be given by the official stance of major NGOs and activist groups towards CM. In this regard, no clear trend has evolved yet. Some environmental NGOs, for instance, are opposed to CM. Notably, Friends of the Earth published in 2018 a report warning of CM (Friends of the Earth, 2018). Likewise, there is a webpage called "Clean Meat Hoax"[35] by animal rights activists that seek to warn of potential dangers of CM. Other NGOs, however, are even in support of CM. Officials of the World Wide Fund for Nature (WWF) have noted positive remarks on CM (A. Watson, 2018); and the German vegetarians' association, ProVeg International, also actively supports CM, as noted above. Other NGOs, such as the UK vegetarian society, remain in a neutral waiting stance (Corbyn, 2020). I suppose it is fair to say that a majority of NGOs can be categorised in this neutral group. Again other NGOs, such as Greenpeace, focus on meat reduction in general, without tacking an explicit stance on either CM or PBM (Greenpeace, 2018). Overall, it appears no clear tendency is observable, also not cross-regionally, and it remains to be seen how the civil society will react.

Subsequently, I turn to the interview results.

Interviews

One theme emerged and that theme is a qualification of the desk-research results: *how the civil society will react will likely depend on properties of CM that are relevant to specific actor segments,* see Table 5-18. This theme means that for certain groups of the civil society, specific issues will be of high importance. For instance: the reaction by environmental protection groups will likely dependent on the energy density of CM; the reaction by animal rights groups will likely dependent on the absence of animal-derived ingredients for CM; and so on.

> Interviewee 19 (policy analyst): *"I think the energy intensity question around cultured meat is likely to make many environmental voices pretty nervous. (…) And the other point, whether in the context of trying to encourage reduced meat consumption for the purposes of planetary health and human health (…) Whether the rise of the cultured meat industry risks having an additive effect rather than a substitution effect on consumption."*, quote #3, Table 5-18

> Interviewee 19 (policy analyst): *"And then the animal welfare and animal rights community. I think it is pretty well known that finding an alternative to fetal bovine serum will be pretty important in terms of winning over the animal rights community and probably consumers more broadly."*, quote #4, Table 5-18

In other words: it appears that the reaction by the civil society will likely not be arbitrary. Instead, it will depend on tangible properties of CM.

Table 5-18: Themes Reaction by the Civil Society.

Theme	Quotes	#
1: How the civil society will react will likely depend on properties of CM that are	Interviewee 2 (investor): *"Most people talk about reduction, right? I think very [few] people understand the technicalities and the intricacies around how exactly we make this happen. (..) It's easy to get lost in the noise."* [27:53]	1

[35] Accessible online at: https://www.cleanmeat-hoax.com/; accessed 06/02/2020.

relevant to specific actor segments	Interviewee 18 (researcher): *"I think by this time [the debate] has become more fact-based, so that the advantages [of CM] are more emphasised."* [03:06]	2
	Interviewee 19 (policy analyst): *"I think the energy intensity question around cultured meat is likely to make many environmental voices pretty nervous. (…) And the other point, whether in the context of trying to encourage reduced meat consumption for the purposes of planetary health and human health (…) Whether the rise of the cultured meat industry risks having an additive effect rather than a substitution effect on consumption."* [15:16]	3
	Interviewee 19 (policy analyst): *"And then the animal welfare and animal rights community. I think it is pretty well known that finding an alternative to fetal bovine serum will be pretty important in terms of winning over the animal rights community and probably consumers more broadly."* [16:08]	4
	Interviewee 20 (investor). *"Things like vegan ways of living and with that also plant-based meat have become more mainstream in the last five years. One says that societally at that there are now even vegan shelves in supermarkets. The topic is generally very strong in the media."* [02:47]	5

I next turn to this function's evaluation.

5.5.3. Evaluation of Function Performance

How does the legitimation differ in both regions? This function was difficult to evaluate, as quantitative data was not analysed. Firstly, lobbying activity. The relative strength of the pro CM lobby versus the anti-CM lobby appears to approximately equal out in both regions. There was no significant advantage of either side in either region identifiable. The development of CM industry associations appears a bit further developed in the US, mainly because of the existence of the Alliance for Meat, Poultry & Seafood Innovation, which unites some of the strongest start-ups in the field. Yet, this is a subtle, not very developed advantage. Next, the relative embracing reaction of incumbent meat producers. It appears that US meat producers are embracing CM more strongly Europe's. Although I have not conducted an exhaustive analysis of investments by meat producers in CM, US' firms are invested of some of the most important CM companies, such as Memphis Meats. Hence, I suggest that the incumbent meat producers in the USA react slightly more positively to CM than Europe's do. Secondly, the reaction by the civil society. In terms of the relative positive reaction of civil society actors, there appears to not be either a clear direction of the civil society reaction in general, nor a distinguishable difference in reaction across regions. Overall it appears that on average the US is leading on function 5, too, see Table 5-19.

Table 5-19: Performance of Function 5: Legitimation.
(For ranking methodology, see section 3.3.2)

#	Function	Indicator	Measure	Comparison vs. Rest of the World: USA	Comparison vs. Rest of the World: Europe	Comparison USA vs. Europe: USA	Comparison USA vs. Europe: Europe
5	Legitimation	Lobbying Activity	Relative strength of pro CM lobby versus anti-CM lobby	Not compared		Approximately on pair*	
			Development of CM industry associations	Not compared		USA leading*	Not leading*
			Relative embracing reaction of incumbent meat producers	Not compared		USA leading*	Not leading*
		Reaction by the Civil Society	Relative positive reactions of civil society actors	Not compared		Approximately on pair*	
		Total average		Not compared		USA leading*	Not leading*

* Based on qualitative data from desk-research.

Next, I explore the 6th function, search guidance.

5.6. Function #6: Search Guidance

5.6.1. Expectations for Near-Time Development

Desk-Research

What are the expectations for CM's near-time development? Collecting primary data on expectations on CM was out of scope for this work; however, there is some previous research existing, namely two studies.

Böhm et al. (2018) conducted semi-structured interviews with five CM experts and seven stakeholders to evaluate their expectations for CM. The results indicate that while some regard CM as *the* promising solution to resolve the issues associated with meat consumption, such as greenhouse gas emissions, see section 1.1, others are not convinced by its potential, and would for instance rather prefer reduced meat consumption as solution strategy. In other words: there was no convergence of expectations observed in the interviews. Yet, the interviews did not focus on issues relatable to tangible near-time development of CM, but more generally to unspecified visions for CM.

Going on more detail on this topic, Tiberius et al. (2019) conducted a two-round Delphi study with 37 (round 1) respectively 30 (round 2) participants, all experts who had published on CM. They asked for participant's opinion for the state of CM and other aspects by the year 2027[36]. Participants were asked on a scale from 1 (low) – 5 (high) their agreement to statements such as "*By the year 2027, cultured meat will be a niche product with a small market share (less than 10 percent)*" (Tiberius et al., 2019, p. 4). Several of the polled statement had relevance to the near-time development of CM. Firstly, in round two, a majority of participants thought that it is more likely than not (25% quartile response: 2; median response: 2) that by 2027 CM has *not* "significantly lower" production cost compared to conventional meat and that CM *cannot* be offered "at a lower price than conventional meat". Only optimists thought for both items that the scenarios are as likely as not (75% quartile response: 3). Secondly, there was a consistent convergence, in round two, that it is more likely than not that CM will be a niche product with less than 10% market share by 2027 (25% quartile response: 4; median response: 4; 75% quartile response: 4)[37]. Thirdly, most participants, in round two, thought that it is more likely than not that CM will be equivalent to conventional meat in appearance and taste by 2027 (median response: 4; 75% quartile response: 4). Only pessimists thought that this would not be the case (25% quartile response: 2). Lastly, there was no convergence by round two whether producing highly structured CM cuts (e.g. steak) by 2027 will be possible, respectively whether CM will be equivalent to conventional meat in texture and structure (for both: 25% quartile response: 2; median response: 3; 75% quartile response: 4). In summary, experts anticipate that CM will at most be a niche product by 2027, without price advantage to conventional meat. Further, they expect that it will be equivalent to conventional meat in appearance and taste, but not in texture and structure, respectively that there will not be highly structured cuts (e.g. steak). Hence, they likely expect equivalence only for unstructured products (e.g. sausage, pasty).

Although these studies indicate interesting general themes for CM's near-time development, they do not allow any inferences on differential cross-regional development between the USA and Europe. I next discuss the results of the interviews.

[36] The paper does not mention when the data was collected, so the time frame of the projection is not known.

[37] In my view this question was, however, problematic for two reasons. Firstly, it did not allow the possibility that CM had *no* market whatsoever. Secondly, it did not allow the possibility that CM was larger than 10%.

Interviews
With regards to the expectations for CM's near-time development, two themes emerged, see Table 5-20. The first relates to the point of market introduction of CM, and what types of products are expected: *in the next few years, market introduction with premium (proto or hybrid) products is expected; commercial scale market introduction is expected in five to 10 years from now*.

> Interviewee 2 (investor): *"I would say in the next few years, you're gonna see very isolated cases of a little bit of sales in hybrid products and high-end restaurants. But in terms of really seeing this stuff in the store shelves that's not 10 times more expensive than the animal-based food – I think it is easily a decade away."*, quote #2, Table 5-20

> Interviewee 8 (supplier employee): *"Based on my understanding (…) in the next two to three years, there will be this mixed meat or ground meat type of product (…) because technically, it's easier, it's less hurdle. But to get the structured cut (…) I think that probably will go beyond more than five to 10 years just because it's so technically challenging to do."*, quote #5, Table 5-20

The second theme is that: *there are concerns that CM is hyped, i.e. that it has too high expectations attached*. The arguments why CM may experience a hype are tied to specific issues.

> Interviewee 8 (supplier employee): *"I also think that maybe the reality will hit the industry soon enough to realise that maybe there will never be a structured meat completely laboratory grown. [That] clean meat will always be some kind of a mix between plant-based materials, cellular-grown laboratory materials – maybe that is the future of clean meat."*, quote #10, Table 5-20

> Interviewee 16 (journalist): *"The reference I thought you were going to make was related to the biofuels industry. A lot of people compare the efficiency of the biofuel industry and how that kind of hit a ceiling. And there was a point where you get a point where you cannot optimise anymore. I think a lot of people are worried that cultured meat might hit the same type of ceiling."*, quote #12, Table 5-20

Table 5-20: Themes Expectations for Near-Time Development.

Theme	Quotes	#
1: In the next few years, market introduction with premium (proto or hybrid) products is expected; commercial scale market introduction is expected in five to 10 years from now	Interviewee 1 (investor): *"I'm looking for 2022 to 2023 for the firsts commercially available products but there's a lot [of] hinges on that."* [43:42]	1
	Interviewee 2 (investor): *"I would say in the next few years, you're gonna see very isolated cases of a little bit of sales in hybrid products and high-end restaurants. But in terms of really seeing this stuff in the store shelves that's not 10 times more expensive than the animal-based food – I think it is easily a decade away."* [10:56]	2
	Interviewee 4 (entrepreneur): *"In Europe (…) the earliest market introduction will be by the end of 2021, early 2022. And when that happens, it's going to be very small scale, very premium. Typical early stage high-tech type of introduction into markets. There may be some earlier introductions in other parts of the world because the regulatory pathway (…) might be a bit more lenient in like Singapore or wherever people are trying to go through the markets. But I guess stage-wise, that's roughly what you're going to see: small introductions into markets in a couple of years, and it's gonna take at least four or five years before the amounts [are] significant."* [03:18]	3
	Interviewee 6 (employee at incumbent): *"I don't see any commercial importance within the next ten years. I think there are so many open issues that need to be resolved successively; so the development will take much much longer."* [03:35]	4
	Interviewee 8 (supplier employee): *"Based on my understanding (…) in the next two to three years, there will be this mixed meat or ground meat type of product (…) because technically, it's easier, it's less hurdle. But to get the structured cut (…) I think that probably will go beyond more than five to 10 years just because it's so technically challenging to do."* [11:01]	5

	Interviewee 19 (policy analyst): *"We're still looking at a timeline of between five and 10 years for something to be commercially available. And then likely in a very, very, small level."* [01:03]	6
	Interviewee 16 (journalist): *"On the marketing conferences, they'll be really excited. (…) They'll say: 'Oh, next year maybe we will have a tasting at this conference, right?' But after conferences like Mark Post's [the international scientific conference on cultured meat in Maastricht, Netherlands] (…) people would come up to me and be like: 'I thought this was going to be here in the next two or three years; now, based off what the scientists are saying, it seems like it's going to be another 10 years at least before it's anywhere'* [46:46]	7
	Interviewee 3 (entrepreneur): *"There's quite a lot of hype in the market right now and a lot of people making pretty big predictions on how quickly they're gonna bring stuff to market. (…) Still some pretty real (…) There still remain some pretty real, scientific challenges. (…) Especially once you start looking at structure tissue, 3D meat products, it needs major R&D. (…) We're still [a] number of years away from products."* [01:40]	8
2: There are concerns that CM is hyped, i.e. that it has too high expectations attached	Interviewee 3 (entrepreneur): *"I think probably that [there] may come a point where – let's say there's a lot of excitement. Any time soon there is going to be a bit of a crash."* [20:26]	9
	Interviewee 8 (supplier employee): *"I also think that maybe the reality will hit the industry soon enough to realise that maybe there will never be a structured meat completely laboratory grown. [That] clean meat will always be some kind of a mix between plant-based materials, cellular-grown laboratory materials – maybe that is the future of clean meat."* [40:29]	10
	Interviewee 10 (NGO employee): *"We are in a hype today. Many investors are interested investing in start-ups. It seems like it is easy today to find money for the start-ups. But we hope that we won't see this investment to go down at one point if the start-ups are not able to deliver what they promise to deliver in the coming months and years."* [14:47]	11
	Interviewee 16 (journalist): *"The reference I thought you were going to make was related to the biofuels industry. A lot of people compare the efficiency of the biofuel industry and how that kind of hit a ceiling. And there was a point where you get a point where you cannot optimise anymore. I think a lot of people are worried that cultured meat might hit the same type of ceiling."* [28:03]	12

Next, I discuss the public awareness for CM.

5.6.2. Public Awareness

Desk-Research

How aware is the public of CM? To best of my knowledge, no research explicitly explored this question so far. Given the constraints of this thesis, a Google Trends analysis appeared to allow a reasonable estimation of public awareness by country, see Appendix L for methodological details.

Figure 5-25 shows the public awareness of CM in USA and Europe, measured by awareness in Germany, the United Kingdom, Netherlands, and France. As one can see in the graph, the public's interest for CM was until 2019 consistently higher in the USA than in Europe. In 2020, only the public's interest in Germany surpassed that of the USA, although the European average still remains substantially below. Despite geographical differences, the public awareness for CM is growing consistently.

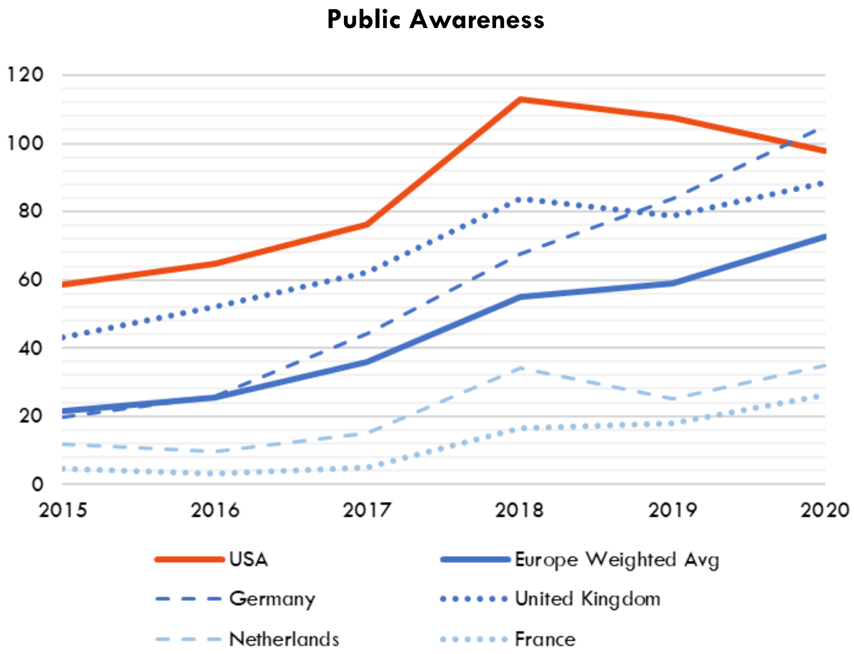

Figure 5-25: Google Searches for CM by Region.
(For derivation of figure data, see Appendix L)

Because the Google Trend analysis was the only means to quantitively understand the public awareness towards CM that was feasible in this thesis, I turn to the interview results.

Interviews

One theme evolved from the interviews: *the attention towards CM is mainstreaming and carried by attention towards PBM*, see Table 5-21.

> Interviewee 19 (policy analyst): *"I guess (…) that there was some degree of conflation [of] the plant-based meat industry and the cultured meat industry."*, quote #4, Table 5-21

> Interviewee 20 (investor): *"I'd say that cultured meat received an external push from plant-based meat (…) it got pulled from it."*, quote #5, Table 5-21

Many participants noted that particularly the initial public offering (IPO) of Beyond Meat supported the public interest in CM. Often, it appeared to interviewees that people could not even differentiate between CM and PBM.

Table 5-21: Themes Public Awareness.

Theme	Quotes	#
1: The attention towards CM is mainstreaming and carried by attention towards PBM	Interviewee 1 (investor): *"And then all of a sudden these plant-based companies start taking off as a convergence of factors helped boost that industry. So now in the past 10 years you had these two parallel industries grow – I don't want to use the term exponentially, but they've ben growing very, very quickly."* [27:05]	1
	Interviewee 16 (journalist): *"Right now, cultured meat is starting to get its first wave of interest outside of food and biotechnology professionals. And I think that [is] because of two factors. One factor is the success of plant-based meat. Not to be confused with cultured meat, because plant-based meat has raised hundreds of millions of dollars. And actually, Beyond Meat has gone IPO [initial public offering] with a great success. (…) And the other reason is [that] we're starting to see more venture dollars go into the industry"* [01:24]	2
	Interviewee 17 (supplier employee): *"Business-like, yes, much has moved recently. In my opinion largely because of the very successful IPO [initial public offering] of Beyond Meat. So many players and investors became aware of the space."* [02:03]	3

	Interviewee 19 (policy analyst): *"I guess (…) that there was some degree of conflation [of] the plant-based meat industry and the cultured meat industry."* [07:55]	4
	Interviewee 20 (investor): *"I'd say that cultured meat received an external push from plant-based meat (…) it got pulled from it."* [01:38]	5

Next, I evaluate the performance of the search guidance.

5.6.3. Evaluation of Function Performance

How does the search guidance differ for both regions? The evaluation of this function is limited by the available data. Almost none of the data collected, neither from the desk-research nor from the interviews, allow an inference on a cross-regional comparison. Only the Google Trends results indicate that the American public is relatively more interested in CM than is Europe's (Figure 5-25). Overall, thus, it appears that the USA is leading in function 6, search guidance, see Table 5-22.

Table 5-22: Performance of Function 6: Search Guidance.
(For ranking methodology, see section 3.3.2)

#	Function	Indicator	Measure	Comparison vs. Rest of the World		Comparison USA vs. Europe	
				USA	Europe	USA	Europe
6	Search Guidance	Expectations for Near-Time Development (~ 10 years)	(No cross-regional results)	No data			
		Public Awareness	Google Trends results	Not compared		USA leading (35%)	Not leading
		Total average		Not compared		USA leading	Not leading

Next, I explore the last function: market formation.

5.7. Function #7: Market Formation

5.7.1. Consumer Acceptance

Desk-Research

What is the expected consumer acceptance for CM in the USA and Europe? As already touched in section 2.2.4, there is data available on the surveyed consumer acceptance in different countries. Figure 5-26 summarises the available data for the USA versus Europe. As observable in the figure, the USA has a substantially higher expected consumer acceptance than in Europe. Given the available survey data, the anticipated willingness to try, eat or buy CM is 49% higher in the USA than in Europe. This cross-regional tendency mirrors what was previously surveyed for novel food technologies, for instance did early studies on GMO consumer acceptance also predicted a higher acceptance in the USA than in Europe (Chern & Rickertsen, 2001).

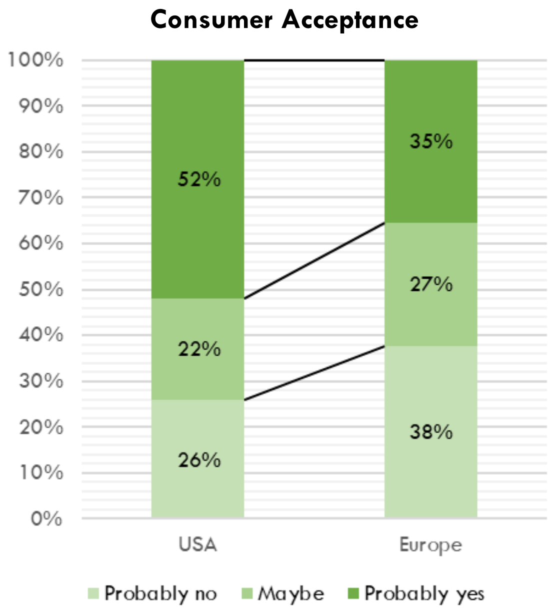

Figure 5-26: Surveyed Consumer Acceptance by Region.
(For derivation of figure data, see Appendix M)

These quantitative results appear to indicate that a higher consumer acceptance can be expected in the USA. I next turn to the results of the interviews.

Interviews

Two themes regarding the consumer acceptance of CM emerged from the interviews, see Table 5-23. The first was: *consumers in Europe are expected to be more sceptical and may require a different messaging approach*. This theme appears to confirm the results of the desk-research.

> Interviewee 21 (governmental official): *"I think that fundamentally Europeans have a different view on it [CM] (…) We are more reluctant and first think about food safety. I think just people are less excited about trying new things here and are less risk-taking. There are much more reservations towards novel processed foods [in Europe] than in the US, one just needs to look at the genetic engineering debate. Nothing, just nothing has moved on this issue even up to recently [in Europe]. For this reason, I think there is still substantial scepticism [in Europe] towards accepting a novel technology [like CM]."*, quote #3, Table 5-23

The second theme that emerged is a more an optimistic outlook: *it does not really matter whether we see broad-range acceptance for CM at the beginning*.

> Interviewee 4 (entrepreneur): *"In any case, even in the South of Europe, there's [a] large enough early adopter base to bring you product to market. I mean, 10 percent of the meat markets would be 350-billion-dollar industry, which is already quite significant."*, quote #6, Table 5-23, Table 5-23

Table 5-23: Themes Consumer Acceptance.

Theme	Quotes	#
1: Consumers in Europe are expected to be more sceptical and may require a different messaging approach	Interviewee 10 (NGO employee): *"I mean they [CM start-ups] are talking about a revolution (…) especially in the US. Maybe (…) it's a message that is great when you're talking to investors, people in foodtech, this kind of people it's fine. But it's problematic when you're talking to the general public (…) I think the idea in Europe is to start with this message and [then] adopt another one, less aggressive one"* [28:04]	1
	Interviewee 12 (researcher): *"That way in Europe [people] are more connected to kind of have romantic ideas about natural food production and a small scale. We want agriculture and the*	2

	countryside being part of our landscapes, and so on. Whereas there's a slightly different culture around that kind of stuff in America. There is kind of a ranch cowboys stereotyping with a whole set of imagery. (…) I think that American consumers will be broadly less sensitive to the idea of processed and unnatural foods. I suppose [they are] less concerned with naturalness (…) than are European consumers." [08:21]	
	Interviewee 21 (governmental official): *"I think that fundamentally Europeans have a different view on it [CM] (…) We are more reluctant and first think about food safety. I think just people are less excited about trying new things here and are less risk-taking. There are much more reservations towards novel processed foods [in Europe] than in the US, one just needs to look at the genetic engineering debate. Nothing, just nothing has moved on this issue even up to recently [in Europe]. For this reason, I think there is still substantial scepticism [in Europe] towards accepting a novel technology [like CM]."* [22:13]	3
2: It does not really matter whether we see broad-range acceptance for CM at the beginning	Interviewee 1 (investor): *"You'll never get 100 percent agreement, 25 percent, roughly 20 25 percent of people in this country [do not agree to CM]. And my understanding throughout Europe [it is similar]. If you get three quarters of the population moving in the right direction, then that's a win."* [25:30]	4
	Interviewee 2 (investor): *"I think a vast majority, if not all, will be able to make that transition [to CM] easily, especially if the meat is indistinguishable and accessible, you know, [if] it doesn't cost a fortune."* [29:57]	5
	Interviewee 4 (entrepreneur): *"In any case, even in the South of Europe, there's [a] large enough early adopter base to bring you product to market. I mean, 10 percent of the meat markets would be 350-billion-dollar industry, which is already quite significant."* [31:27]	6

Next, I explore the results regarding regulation.

5.7.2. Regulation

Desk-Research

What is the expected regulatory approval ease for CM in the USA and Europe? For this question, the desk-research was already discussed in section 4.4. Hence, I subsequently explore directly the interview results.

Interviews

In the interviews two themes with relation to regulation emerged, see Table 5-24. The first was: *if CM contains GMOs, it will be more problematic in Europe, but also burdensome in the USA*. In Europe interviewees had no doubt that it would be tiresome:

> Interviewee 1 (investor): *"My concern is that if a company is developing a product for the US market, it may not be readily available in Europe if it is genetically modified (…) In Europe, they would presume we'd be developing a GMO free product for the European market, that would be easier regulatory"*, quote #1, Table 5-24

But also the same process is not considered easy in the US by experts:

> Interviewee 14 (lawyer): *"In the US there's this misconception that the regulatory process in the US is not burdensome (…) But it has been for bio-engineered foods. I think anybody who knows a lot about the regulatory framework will tell you: this is why the bio engineering landscape has been dominated by big companies. Because only big companies have the resources to get through that entire process (…) It does take some time to create a bio-engineered food and get it in the market"*, quote #5, Table 5-24

A second theme that involved is: *the regulation process is formally apolitical in both regions but can be influenced in both at some stage*. In Europe the politicisation lays after a risk assessment was made by EFSA:

Interviewee 13 (lawyer): *"In European food law one differentiates between risk assessment and risk management (…) [During risk management] the Standing Committee is accountable for negotiating the implementing act. And that is a political process, naturally. It is clearly possible that risk management decisions deviate from the risk assessment."*, quote #7, Table 5-24

In the USA, in comparison, the politicisation lays in influencing the legislation itself, particularly for labelling:

Interviewee 14 (lawyer): *"When [in the USA] one of these companies went through a pre-market evaluation process with FDA, and FDA concluded that it had no question, there isn't a political process attached with that. It doesn't have to go through review by members of congress, et cetera. But the way that people can insert themselves into the process is to lobby congress or lobby the state governments and say that this technology should be regulated another way. And the way we see that play out more often than not is through labelling (…) [the] state legislature related to labelling (…) I think that's where you're going to see the politicisation of the issue here in the US"*, quote #9, Table 5-24

Lastly, interesting to note, one interviewee confirmed the expected duration for the approval process in the USA:

Interviewee 14 (lawyer): *"I would say that realistically we're looking at anywhere between six months to three years [to get market approval for CM in the USA]. Six months would be pretty extraordinary"*, quote #10, Table 5-24

Table 5-24: Themes Regulation.

Theme	Quotes	#
1: If CM contains GMOs, it will be more problematic in Europe, but also burdensome in the USA	Interviewee 1 (investor): *"My concern is that if a company is developing a product for the US market, it may not be readily available in Europe if it is genetically modified (…) In Europe, they would presume we'd be developing a GMO free product for the European market, that would be easier regulatory"* [12:08]	1
	Interviewee 10 (NGO employee): *"[Genetic modification] would make it just more complex [in Europe]. But most of the [European] start-ups try not to use genetic modification."* [35:33]	2
	Interviewee 13 (lawyer): *"EFSA is under pressure to not make a mistake. The glyphosate case was an absolute catastrophe."* [36:24] [Glyphosate was approved by EFSA but is now in the process of getting prohibited in Europe after claims that it is not safe were made.]	3
	Interviewee 14 (lawyer): *"[If CM contains GMOs] it will make a difference in that it will have to be evaluated [in the USA], right? (…) The safety evaluation would have to take that into consideration. [But] it doesn't trigger (…) a whole other regulatory process like the GMO regulations in the EU (…) And we have a lot of precedent for that [GMO-containing approved foods] in the US, right? Even Impossible Burger was developed using genetically engineering."* [35:09]	4
	Interviewee 14 (lawyer): *"In the US there's this misconception that the regulatory process in the US is not burdensome (…) But it has been for bio-engineered foods. I think anybody who knows a lot about the regulatory framework will tell you: this is why the bio engineering landscape has been dominated by big companies. Because only big companies have the resources to get through that entire process (…) It does take some time to create a bio-engineered food and get it in the market"* [21:24]	5
2: The regulation process is formally apolitical in both regions but can be influenced in both at some stage	Interviewee 4 (entrepreneur): *"There's a regulation in Europe and food regulation that one could argue is maybe not the most efficient regulation out there, but it is very thorough. And the scientific evaluation in Europe is very unbiased. It's not influenced by influence groups. (…) In any way, getting the regulation in place in Europe, which is the step that comes after you scientifically evaluated what you're doing, that's a different story. That is a political process. And then guess Europe will be more complex than maybe any other part in the world. (…) Countries simply have to vote and, well, there are 27 member states. You can vote against it for whatever reason. So if scientifically what we're doing is okay, the French, for instance, can still say: 'I don't like this, I vote against that, that's where*	6

	my farmer's [interest lays] or whatever. You do need to have some level of let's say intelligence in that area to know what member states are going to do and try to influence them." [18:20]	
	Interviewee 13 (lawyer): *"In European food law one differentiates between risk assessment and risk management (…) [During risk management] the Standing Committee is accountable for negotiating the implementing act. And that is a political process, naturally. It is clearly possible that risk management decisions deviate from the risk assessment."* [26:07]	7
	Interviewee 14 (lawyer): *"I want to comment on the risk assessment piece. I think the analysis, the fundamentals of the analysis, are not going to be, from the US model versus an EU model, are not going to be substantially different (…) It's a matter of semantics. What EFSA versus USDA might look at from a scientific perspective is probably similar. What I think is different is just the legal mechanism."* [13:10]	8
	Interviewee 14 (lawyer): *"When [in the USA] one of these companies went through a pre-market evaluation process with FDA, and FDA concluded that it had no question, there isn't a political process attached with that. It doesn't have to go through review by members of congress, et cetera. But the way that people can insert themselves into the process is to lobby congress or lobby the state governments and say that this technology should be regulated another way. And the way we see that play out more often than not is through labelling (…) [the] state legislature related to labelling (…) I think that's where you're going to see the politicisation of the issue here in the US"* [30:54]	9
Other	Interviewee 14 (lawyer): *"I would say that realistically we're looking at anywhere between six months to three years [to get market approval for CM in the USA]. Six months would be pretty extraordinary"* [20:41]	10

Next, I evaluate the performance of the function market formation.

5.7.3. Evaluation of Function Performance

How does the market formation differ between both regions? Regarding consumer acceptance, the USA appears to be leading in terms of surveyed consumer acceptance (Figure 5-26) and what interviewees mentioned about it. For regulation, the approval process duration appears to be about similar for both regions: 18-24 month in Europe (see section 4.4) and 6 to 36 months in the USA (see interviews in this section). Hence: although the USA has a higher variance, the expected average can be argued to be comparable. A second measure is how more or less difficult the regulation process would be if CM will contain GMOs. On this metric, the US regulation is likely to be easier to go through, interviewees noted, albeit also not without problems. Regarding the politicisation of the regulatory process, both regions appear approximately on pair, although the stage at which this politicisation may take place differs. Overall it appears that the US is stronger in the market formation than Europe, see Table 5-25.

Table 5-25: Performance of Function 7: Market Formation.
(For ranking methodology, see section 3.3.2)

#	Function	Indicator	Measure	Comparison vs. Rest of the World USA	Comparison vs. Rest of the World Europe	Comparison USA vs. Europe USA	Comparison USA vs. Europe Europe
7	Market Formation	Consumer Acceptance	Surveyed consumer acceptance	Not compared		USA leading (49%)	Not leading
			Interviewees expected consumer acceptance	Not compared		USA leading*	Not leading*
		Regulation	Approval process duration	Not compared		Approximately on pair*	
			Difficulty if containing GMOs	Not compared		USA leading*	Not leading*
			Politicisation of process	Not compared		Approximately on pair*	
		Total average		Not compared		USA leading	Not leading

* Based on qualitative data from desk-research and interviews.

Having explored all the functions, I next conclude this section and answer the research question.

5.8. Section Conclusion

In this section I sought to answer research question 2: *How does the functional performance of the cultivated meat innovation system compare in the assessed regions?* In this section, I subsequently evaluated the function performance of the seven TIS functions, which I subsequently summarise.

In a comparison between the USA and Europe, the USA appears to be leading on every function measured, see Table 5-26. The strength of the TIS for CM in the USA can thus be argued to be consistently stronger in depth and breadth. The single only indicator Europe appears to be leading is public research output, see section 5.1.1. I explore the significance of this circumstance in the discussion, see section 7.1.1.

In a comparison versus the rest of the world, USA is clearly on the 1st place, with Europe coming on an unclear 2nd / 3rd spot. On all functions measured, the USA came on 1st spot versus the rest of the world. Hence: the USA has worldwide the strongest TIS for CM. For Europe, the picture is less clear. While it is second on knowledge development and diffusion and resource mobilisation, it has an unclear 2nd / 3rd place for entrepreneurial activity and a 3rd / 4th spot for positive externalities. For entrepreneurial activity, Europe is contented by Israel for the 2nd spot, and for positive externalities by the Asia-Pacific region.

Table 5-26: Overall Function Performance.
(For ranking methodology, see section 3.3.2)

#	Function	Comparison vs. Rest of the World		Comparison USA vs. Europe	
		USA	Europe	USA	Europe
1	Knowledge Development and Diffusion	1st	2nd	USA leading	Not leading
2	Entrepreneurial activity	1st	2nd / 3rd	USA leading	Not leading
3	Resource Mobilisation	1st	2nd	USA leading	Not leading
4	Positive Externalities	1st	3rd / 4th	USA leading	Not leading
5	Legitimation	Not compared		USA leading	Not leading
6	Search Guidance	Not compared		USA leading	Not leading
7	Market Formation	Not compared		USA leading	Not leading
	Total average	1st	2nd / 3rd	USA leading	Not leading

To answer research question 2 in summary: the TIS for CM is strong in both the USA and Europe compared to the rest of the world. However, the USA is clearly number one, and Europe at an unclear 2nd or 3rd place. Overall, the US' TIS for CM is consistently strong than Europe's.

6. Results 3: Thematic Analysis

In this section I answer research questions 3: *What themes with importance to the near-time development of the cultivated meat industry can be identified?* As described in the methodology, section 3.3, the thematic analysis in this section contains the residues themes that arose from the interviews.

In the thematic analysis, two thematic areas with importance to the near-time development of the CM industry were identified: the development of the technological system and the supply chain. Both themes received a significant number of contributions and for both several interesting points were mentioned by interviewees. Although also other themes emerged from the interviews, there was insufficient convergence among interviewees to present them here. As mentioned in the method in section, insufficient convergence means that the same theme was not raised by at least two interviewees independently. The results are subsequently presented like the interview sections in the functional analysis.

6.1. Technological System Development

Five themes were identified with relevance to the development of the technological system. The themes illustrate current and upcoming technological challenges for the development of CM.

The first theme is: *CM companies are still deep in R&D phase and a pilot plant is the next step*, see all quotes in Table 6-1. That CM companies are still in the R&D phase is probably undisputable at the point of writing. However, what that actually *means* illustrates what might be the next step in the development of CM's technological system.

> Interviewee 5 (NGO employee): *"Four or five years ago the first cultivated meat companies were initiated (…) Most of them are in what I would define as early-stage research. We're starting to see a couple interested in building pilot scale facilities, but, at least to my knowledge, none of that has happened yet. So, everything is still like bench type work. Working with small amounts of cells, and still trying to refine scientific protocols."*, quote #1, Table 6-1

The next step appears to be building a pilot plant.

> Interviewee 16 (journalist): *"I mean, I don't think anybody's actually going beyond pilot scale. I don't think anybody is going to [do] this [in] industrial scale yet. I know that everyone is planning for it. But I guess, if they do, then things will start moving very fast (…) And it's also, if you consider the amount of money that's raised in the industry, none of that is enough to go to a very large industrial scale yet"*, quote #8, Table 6-1

Table 6-1: Technological System Development Theme 1.

Theme	Quotes	#
1: CM companies are still deep in R&D phase and a pilot plant is the next step	Interviewee 5 (NGO employee): *"Four or five years ago the first cultivated meat companies were initiated (…) Most of them are in what I would define as early-stage research. We're starting to see a couple interested in building pilot scale facilities, but, at least to my knowledge, none of that has happened yet. So, everything is still like bench type work. Working with small amounts of cells, and still trying to refine scientific protocols."* [01:03]	1
	Interviewee 6 (employee at incumbent): *"I have a relatively clear opinion on this. I think that the whole sector or industry is still in the absolute beginning phase (…) it is essentially research driven. There are still a very high number of hurdles ahead of a commercial production."* [03:11]	2
	Interviewee 21 (governmental official): *"My perception is that so far one can produce it in small quantities. But the next steps still raise many questions. From my point of view the next step is to move out of a laboratory phase into a phase that at least remotely resembles one in which one can produce [CM] in a scale to delivery restaurants."* [00:40]	3

	Interviewee 7 (journalist): *„The state [of the industry] is, I'd say: there is no larger production of cultivated meat yet to my knowledge. Hence, everything we see right now is on a lab-scale (…) The next step is to produce larger quantities (…) to demonstrate that it is possible to produce it in larger quantities"* [01:49]	4
	Interviewee 8 (supplier employee): *„We are primarily selling* blackened *[to CM companies] We have seen the revenue increase year after year. We know that this may have something to do with their situation. It means that they're actually doing more research [CM companies]"* [03:06]	5
	Interviewee 10 (NGO employee): *„They [CM start-ups] don't have a pilot plant yet (…) We are not even at this point."* [02:46]	6
	Interviewee 16 (journalist): *"I mean, I don't think anybody's actually going beyond pilot scale. I don't think anybody is going to [do] this [in] industrial scale yet. I know that everyone is planning for it. But I guess, if they do, then things will start moving very fast (…) And it's also, if you consider the amount of money that's raised in the industry, none of that is enough to go to a very large industrial scale yet"* [24:15]	7
	Interviewee 17 (supplier employee): *"From a technological standpoint I have the perception that with the main technological problems most firms that I know have not substantially advanced [recently], for instance serum-free respectively animal-free medium."* [00:48]	8
	Interviewee 20 (investor): *„The whole industry is still relatively strong in the research phase. There are intents to be able to produce within the next two, three or four years [CM] in continuous operations (…) a mini commercialization"* [00:58]	9
	Interviewee 2 (investor): *"It is more of an engineering challenge then requiring scientific breakthroughs"* [00:51]	10

The next theme that emerged from the interview explains what it actually means wanting to upscale the production to a pilot plant: *the goal of production upscaling is cost reduction*, see Table 6-2.

> Interviewee 9 (researcher): *"All of it is driven by costs to some degree (…) It's clearly going to be an overriding issue for a while until you can find the right ways to keep costs [down]"*, quote #4, Table 6-2
>
> Interviewee 7 (journalist): *„The first factory – that is extremely difficult. The first factory has extremely high cost."*, quote #4, Table 6-2

Table 6-2: Technological System Development Theme 2.

Theme	Quotes	#
2: Goal of production upscaling is cost reduction	Interviewee 4 (entrepreneur): *"If we bring down the cost down [in absolute terms] from tens of thousands per kilo to maybe hundreds per kilo (…) But that's not where the fun is. The fun is getting it from hundreds per kilo to 1 or 0.5 per kilo. The first bit is the most appealing, because you can say: 'Hey, I reduced the price of my burger by 10,000€ or 100,000€'. But that's not where the tricky bit is. The tricky bit is in the last 50 cents, 1€, 5€, getting that price. That's going to take as much energy as getting off the big chunks"* [10:58]	1
	Interviewee 5 (NGO employee): *"I think the advantage for this industry is that the biomedical industry and the food industry knows how to build large scale manufacturing facilities. We produce many, many high-quality pharmaceuticals and therapeutics, and we use cell culture processes to brew beer and produce yoghurt and things (…) I don't have concerns about the ability to produce [CM] from a technical perspective (…) But I think (…) there are certainly some challenges around the translation of the technology, particularly as it pertains to cost"* [05:27]	2
	Interviewee 7 (journalist): *„The first factory – that is extremely difficult. The first factory has extremely high cost."* [14:47]	3
	Interviewee 9 (researcher): *"All of it is driven by costs to some degree (…) It's clearly going to be an overriding issue for a while until you can find the right ways to keep costs [down]"* [18:04]	4
	Interviewee 16 (journalist): *"I think if you look at the costs associated with cultured meat (…) We know it will get cheaper, but it's not something that will happen overnight."* [28:03]	5
	Interviewee 17 (supplier employee): *"Indeed I am the opinion that the efficiency or productivity of these new [CM] products or processes need to be brought necessarily to the next level"* [03:31]	6

	Interviewee 19 (policy analyst): *"And another key takeaway I guess from the conversations I've had over the past year is that there are still some major challenges to scale up."* [01:25]	7

The next two themes related to what aspect of the technological systems requires optimization to reduce costs. The first is: *for reducing production cost, particularly reducing the cost of growth media is a challenge*, see Table 6-3.

> Interviewee 4 (entrepreneur): *"I would say that most if not all [CM start-ups] have in common is that they're working [on] price. Ultimately, if you wanted to have a process that is capable of making affordable [cultivated] meat (…) Then this is actually the central issue. You need to have a cell growth media (…) that is extremely cheap. Just to give you an idea, today growth media is sourced from the pharmaceutical industry (…) The pricing has to come down roughly 100,000-fold to be able to grow [cultivated] meat (…) at a large scale at a competitive price. This may sound crazy but at the same you have to see that it's pharmaceutical product (…) There's a lot of unspecific costing in the price you pay today"*, quote #2, Table 6-3

That reducing the cost of growth media is a key, or *the* key challenge for reducing cost is a known fact in the CM industry (e.g. GFI, 2019f).

Table 6-3: Technological System Development Theme 3.

Theme	Quotes	#
3: For reducing production cost, particularly reducing the cost of growth media is a challenge	Interviewee 3 (entrepreneur): *"There are major media suppliers in the pharmaceutical industry and they're trying to figure out: 'Hey this cultivated meat could be a huge next industry and media is such an important part of it' (…) I certainly think that if they can crack low cost media then it's gonna be a massive contribution to the development of the industry"* [07:49]	1
	Interviewee 4 (entrepreneur): *"I would say that most if not all [CM start-ups] have in common is that they're working [on] price. Ultimately, if you wanted to have a process that is capable of making affordable [cultivated] meat (…) Then this is actually the central issue. You need to have a cell growth media (…) that is extremely cheap. Just to give you an idea, today growth media is sourced from the pharmaceutical industry (…)The pricing has to come down roughly 100,000-fold to be able to grow [cultivated] meat (…) at a large scale at a competitive price. This may sound crazy but at the same you have to see that it's pharmaceutical product (…) There's a lot of unspecific costing in the price you pay today"* [04:48]	2
	Interviewee 8 (supplier employee): *"We actually think that eventually the food grade media will have some other regulatory requirements and safety requirements as pharmaceutical grade (…) Maybe the number of testing would be less stringent than the pharmaceutical grade. But nobody really knows what is a food grade media at this time (…) I think that's going to be a very challenging question for companies like [a medium producer] We are in the areas of high margin and low volume (…) And this is actually a high volume, low margin [product]"* [17:04]	3
	Interviewee 17 (supplier employee): *"One additional factor is whether cell growth medium is used in an efficient manner. With one litre cell growth medium one can produce some milligrams [cultivated] meat, or if one is efficient a few grams. That's a very substantial difference."* [07:40]	4

The next theme in this context was: *there are many uncertainties how to design an overall efficient CM production system,* see Table 6-4.

> Interviewee 9 (researcher): *"You have to take a, what I call, a systems approach. You need to consider the cells, you need to consider the media, you need to consider the matrices, the biomaterials, you need to consider the housing, the bioreactor, you need to consider all of it. You also have to think about the downstream processing (…) how do you get to the final material?"*, quote #4, Table 6-4

In the interviews several uncertain aspects of the production system were pointed out, such as the mere availability of production hardware, the sterilisation of large-scale bioreactors, or energy supply for the production system. The quotes illustrate clearly the degree of uncertainty that is still apparent for the production system of CM.

Table 6-4: Technological System Development Theme 4.

Theme	Quotes	#
4: There are many uncertainties how to design an overall efficient CM production system	Interviewee 5 (NGO employee): *"For the cell therapy industry, if you're charging a 1 million dollars, the cost of growth factors is immaterial, really. If the dose is micrograms of cells, then the scale of the bioreactor is also not a significant question to ask. Opposed to if you're trying to create kilos of muscle and fat tissue (…) Just that spatial question: how does it actually look like to do it at that scale? (…) is very different."* [26:02]	1
	Interviewee 6 (employee at incumbent): *"In comparison to the plant-based meat one needs in principle everything – one needs a new hardware. One cannot fall back on pre-existing equipment like for plant-based meat. There you have the extrusion machines and at the end of the day, if you put conventional meat through it or plant-based meat – sure, you need to adjust the parameters – but you can use the equipment. But for cultivated meat one needs novel bioreactors, which are currently too small and therefore uneconomical, but when one wants to utilize a bigger sized version then one needs to invest [in developing it] (…) So the cost structure [of cultivated meat] is initially very unfavorable: one has high CapEx [capital expenses] and I believe that the running cost, at least currently, are also relatively high, especially for the medium."* [07:40]	2
	Interviewee 21 (governmental official): *I think there are several hurdles (…) How will one produce sterile? Currently that might not be an issue with a small laboratory with ten or 100 litre tanks. But how does it work with 10,000 litre tanks? (…) Another question is the question of energy utilisation. Maybe the production facilities will not be in Europe, but where one has cheap and widely available solar energy. But then it [CM] must be transported again."* [02:10]	3
	Interviewee 9 (researcher): *"You have to take a, what I call a systems approach. You need to consider the cells, you need to consider the media, you need to consider the matrices, the biomaterials, you need to consider the housing, the bioreactor, you need to consider all of it. You also have to think about the downstream processing (…) how do you get to the final material?"* [16:48]	4
	Interviewee 11 (researcher): *"So what I can say is that there are access points from many different avenues on which people work. Be it cell line development to media optimisation, new scaffolds, new upscaling methods, in every step something [research] is already there. But what is missing currently is to bring everything together. Everybody is busy with one partial steps (…) There is not yet the connection of the partial steps"* [03:08]	5

The last theme that emerged from the interviews is: *producing structured 3D CM is technologically substantially more challenging than unstructured 2D meat*, see Table 6-5.

> Interviewee 8 (supplier employee): *"When it comes to the structured meat, it is technically just so challenging. I mean, you're trying to do a billion years of evolution (…) within 20 years, 10 years to create this meat. It is just simply not possible"*, quote #4, Table 6-5

This theme therefore mirrors the expectations by experts (Tiberius et al., 2019), see section 5.6.1.

On a more detail level, interviewees noted particularly that the equipment for growing 3D CM is missing, that vascularization – the supply of CM with nutrients and waste removal – is a key challenge, and that maybe 3D printing of CM is a solution.

Table 6-5: Technological System Development Theme 5.

Theme	Quotes	#
5: Producing structured 3D CM is technologically substantially more challenging than unstructured 2D meat	Interviewee 2 (investor): *"I don't think we're anywhere close (…) in terms of real cuts of meat (…) What I think a lot about is displacing industrial animal agriculture. When you look at a cow and the whole carcass: yes, there' a lot of trimming and fat used for ground beef and that's a lot of product we have. But the vast majority is the whole cuts (…) Also in terms of economic value, that's where most of the money is (…) That's a tricky one. There are some start-ups looking at this. In terms of 3D-printing and 3D texturing (…) But the bar is even higher when we're talking about whole cuts of meats in terms of the sensory expectations."* [06:23]	1
	Interviewee 3 (entrepreneur): *"Especially once you start looking at structured tissue, 3D meat products, it's major R&D that needs to happen before anything really comes to market."* [01:40]	2

	Interviewee 5 (NGO employee): *"For more complex food products, we probably don't have the system, the equipment in place today that could be used for large-scale production. For something like ground [cultivated] meat products, I imagine we can iterate on existing technologies. But if you think about something more complex, three dimensional tissue like a steak or like a piece of pork or a piece of fish, I'm not sure that the technology that's available today that is used by the pharmaceutical industry, the cell therapy industry, can just be taken and placed inside a cultivated meat production facility and used"* [05:54]	3
	Interviewee 8 (supplier employee): *"When it comes to the structured meat, it is technically just so challenging. I mean, you're trying to do a billion years of evolution (…) within 20 years, 10 years to create this meat. It is just simply not possible"* [44:05]	4
	Interviewee 11 (researcher): *"[In biomedicine] one can do simple things quite well (…) Gristle works quite well, and skin works quite well. Because both are things that do not require vascularisation (…) But for all other things it does not work like that. And for that reason, many biomedical approaches hinge on this question of vascularisation, the supply of the tissues. Regarding cultivated meat, if you think about the classical approach by Mark Post, with the ground beef, you don't need it [vascularisation]. Because one just presses it together afterwards, and before everything [nutrients etc.] can get where you need them. But if you really want to also grow a steak in the laboratory (…) then it would also be sensible if one has a blood vessel system (…) Or you print it [the CM]."* [13:18]	5
	Interviewee 17 (supplier employee): *"One thing I would consider is the 3D printing technology. One limitation of this industry is that one so far cannot do very large three-dimensional structures because (…) one is not yet capable to create delicate 3D [blood vessels] within the larger 3D tissue (…) If one can 3D print [the CM], maybe one does not need a pre-defined 3D structure [for vascularisation]"* [27:20]	6

Having presented the interview results pertaining to the development of the technological system, I next present those with regards to the development of the supply chain.

6.2. Supply Chain Development

Three themes were identified with respect to the supply chain development. With a supply chain I refer to the network of organisations and processes involved in the provision of a good or service, comprising upstream and downstream elements (e.g. Frostenson & Prenkert, 2015).

The first theme is: *there is little division of work in the CM industry yet, but a differentiated supply chain likely needs to evolve*, see Table 6-6. To understand this point, interviewees made at several occasions comparisons to more established industries.

> Interviewee 16 (journalist): *"If you think about a car, if you look at like a Mercedes, 200 plus different companies work on each single [car]. It is managed by Mercedes, but so many different companies [are involved], somebody makes the transmission, somebody might make the pistons, the breaks (…) And honestly I think it will have to be like that for cultured meat as well",* quote #8, Table 6-6

This theme basically illustrates the need for a differentiation for firms within an overall supply chain for CM, which currently does not exist yet. Several interviewees noted how inefficient the CM industry currently operates because most start-ups try to be the focal company. Rather, they suggested that CM start-ups need to fine niches to which they contribute towards an overall work division of the industry.

Table 6-6: Supply Chain Development Theme 1.

Theme	Quotes	#
1: There is little division of work in the CM industry yet, but a differentiated supply chain likely needs to evolve	Interviewee 9 (researcher): *"There's lots of [research] in the private domain we don't know, and you still go ahead and do this. And later on you find out, when you talk to your colleagues 'We did that 10 years ago, but didn't publish it'"* [09:06]	1
	Interviewee 8 (supplier employee): *"I think almost 80 percent of them [CM start-ups] all started saying that they want to become a clean meat company at the end of the day. I think that's what they have to say to raise money. And the only one that seems to be moving in that direction is [a US-*	2

	based CM start-up]. But I don't think that many of the companies will eventually become clean meat companies. They probably will be acquired, or they license out their technologies and have (…) big companies like Tyson to be the one in charge of producing the meat, using their technologies. Because they simply don't have the funding to do that. Everybody is (…) working on the cell line, the technology to grow the cells, the technologies to differentiate the cells and maybe some bioreactors. That's fine. But everything upstream, in terms of the materials, the media, that needs to be fed into the final manufacturing, nobody's working on that. That's going to be their limitation." [24:46]	
	Interviewee 2 (investor): *"I mean, the failure rate invariably will be quite high, right? If we look at 50 teams, a good majority of them will fail. If that wasn't the case, it would be a huge anomaly, like any new industry"* [18:10]	3
	Interviewee 15 (NGO employee): *"For most part, these companies are just working on platforms or they want to be able to eventually produce all kinds of meat, despite slightly changing the process"* [07:18]	4
	Interviewee 4 (entrepreneur): *"We already know that ultimately that should be possible [producing CM at scale]. But the process towards that and developing the supply chain that's going to produce the stuff at a huge scale. And this is a supply chain that essential does not exist today. It's simply not there. Yeah, that's gonna take a long time"* [05:51]	5
	Interviewee 1 (investor): *"If you look at the conventional agriculture world ecosystem, you need seeds companies, seeds coding companies, you need distribution partners, you need, if you talk about animal agriculture, you would need lots meat lots, meat packers, cold chain, the whole works. Where is the John Deere of the cultivated meat world?"* [16:22]	6
	Interviewee 5 (NGO employee): *"Maybe in the future we reach a point where they're reliant on the B2B companies, but as of now, until very recently, there were no B2B companies. All these producers have to just rely on building the entire process themselves (…) If we're at scale, it would be best to have a specialist making media and the specialist making scaffolds and a specialist bringing it all together"* [08:55]	7
	Interviewee 16 (journalist): *"If you think about a car, if you look at like a Mercedes, 200 plus different companies work on each single [car]. It is managed by Mercedes, but so many different companies [are involved], somebody makes the transmission, somebody might make the pistons, the breaks (…) And honestly I think it will have to be like that for cultured meat as well"* [17:00]	8
	Interviewee 17 (supplier employee): *"Our experience is that most start-ups want to try at first to develop cell lines themselves, and in this context matching cell culture media (…) So far collaborating with them is quite difficult (…) From a scientific point of view I find this a bit silly (…) We start with the same information and after half a year we talk again and ask: 'Ah, how much have you advanced?' In principle one has the same work everywhere and money is getting thrown away. It is a little bit lavish"* [31:56]	9

The next theme indicated that *the first signs for the development of a differentiated supply chain are visible*, see Table 6-7. Hence, it indicates that a response is already under way.

> Interviewee 15 (NGO employee): *"[We are seeing] kind of a sub industry to service these companies emerge. Some of them are start-ups that exists solely to sell things to other cultivated meat start-ups, and some of them are life sciences companies that are creating subsidiaries or product lines for these companies (…) I think that's probably one of the biggest recent developments"*, quote #5, Table 6-7

Table 6-7: Supply Chain Development Theme 2.

Theme	Quotes	#
2: The first signs for the development of a differentiated supply chain are visible	Interviewee 3 (entrepreneur): *"There are some companies trying to do the full virtual stack or other companies trying to do particularly parts of the value chain. Right now, it is still early (…) Right now it's difficult to (…) People have ideas, but everyone really is still in the R&D phase. Until people are out of R&D, it is difficult to say where they're going to end up in the value chain"* [09:11]	1
	Interviewee 10 (NGO employee): *"We already see some companies specialised in bioreactors, specialised in media. I think it might help; it will help the field to move faster"* [17:36]	2
	Interviewee 8 (supplier employee): *"You will see more start-up coming up in the next few years, for sure. These are going to be start-ups with some new technologies out there that will fill in the gaps in the entire value chain of clean meat manufacturing."* [03:48]	3

	Interviewee 20 (investor): *"I find it interesting that still relatively many firms indeed have the approach of wanting to do everything by themselves. I see that slowly this fades out, but only very hesitantly. It will be interesting to see whether the companies that earlier open to partnerships will be more successful than others. That's something I can imagine very well."* [22:50]	4
	Interviewee 15 (NGO employee): *"[We are seeing] kind of a sub industry to service these companies emerge. Some of them are start-ups that exists solely to sell things to other cultivated meat start-ups, and some of them are life sciences companies that are creating subsidiaries or product lines for these companies (…) I think that's probably one of the biggest recent developments"* [01:11]	5
	Interviewee 5 (NGO employee): *"[We are seeing] some start-ups that are focused on developing cell culture media and lower cost growth factors specifically for the cultivated meat"* [09:00]	6

The next theme is that *CM will likely be produced locally*, see Table 6-8. Several interviewees came to this conclusion, some because of technological or logistical reasons, others for cultural reasons.

> Interviewee 16 (journalist): *"When we're talking about large scale manufacturing, strategically, they build these manufacturing hubs right next to the inputs. And you almost have to do that, otherwise shipping things around is just not going to be cost effective (…) The original plant from [a CM start-up in the USA] was originally or is supposed to be in [a city in California]. I mean, that doesn't make sense at all to me. If anything, it would make – if you're talking about the US – I think it would make sense to be at the center of the country where all the corn is grown, as agricultural center. It's also a shipping center (…) And we see that with Beyond Meat. Beyond Meat manufactures in Missouri, that's pretty central."*, quote #3, Table 6-8

Indeed, from a supply chain perspective, it is conventional knowledge that manufacturing centers for so-called "weight-gaining" products, i.e. products that cumulate inputs, are located closer to points of consumption than "weight-loosing" products (Bramel & Simchi-Levi, 1997; A. Weber, 1929). CM is most likely a weight-gaining product.

Table 6-8: Supply Chain Development Theme 3.

Theme	Quotes	#
3: CM will likely be produced locally	Interviewee 8 (supplier employee): *"I think that in the future, most likely (…) it will almost be like the oil industry. You have the distillery right next to the, how the robbers are made, how the different chemicals are extracted by different companies. They all setting up their factory adjacent to the distillery. The distillery approach maybe the way to produce the media"* [25:26]	1
	Interviewee 8 (supplier employee): *"There has to be this connection to the raw material supply chain (…) All of this is best adjacent to the final bioreactors where the clean meat is produced. It cannot just be transported in the dry powder or liquid of media from somewhere else. Especially if you want reduce cost. Anytime you use a truck or trains to ship this raw material, you increase the cost. So it almost needs to be almost directly next to it (…) Another topic nobody talks about is water. You have all the [growth media] powder but it needs to be mixed in some liquid. So the water is so important. The water cannot be shipped by cartons or bottles. It [the CM factory] almost needs to be located near to a river or a water reservoir. And the water comes in, it needs to be sterilised, filtered, onsite, immediately near the mixer, where the dry powders are mixed with the water. That's gonna be a huge business: water filtration, membranes for sterilisation, and all that."* [27:17]	2
	Interviewee 16 (journalist): *When we're talking about large scale manufacturing, strategically, they build these manufacturing hubs right next to the inputs. And you almost have to do that, otherwise shipping things around is just not going to be cost effective (…) The original plant from [a CM start-up in the USA] was originally or is supposed to be in [a city in California]. I mean, that doesn't make sense at all to me. If anything, it would make – if you're talking about the US – I think it would make sense to be at the center of the country where all the corn is grown, as agricultural center. It's also a shipping center (…) And we see that with Beyond Meat. Beyond Meat manufactures in Missouri, that's pretty central."* [31:44]	3
	Interviewee 7 (journalist): *"I'm not afraid that there will be some Nestlé who controls the cultivated meat industry all over the world. Food is still something very regional, and one needs regional answers"* [37:45]	4

Having presented all themes that emerged from the thematic analysis, I next summarise this section and provide the answer to the research question.

6.3. Section Conclusion

In this section I sought to answer research questions 3: *What themes with importance to the near-time development of the cultivated meat industry can be identified?*

Overall, two meta-themes with relevance to the near-time development of the CM industry were identified: the development of the technological system and the development of the supply chain.

Figure 6-1 summarises the themes for the technological system. The main topic that emerged is that CM start-ups are still deep in R&D phase and that a pilot plant is probably the next logical development step. Interviewees noted that a commercial-scale plant is probably still far off. The goal of this production upscaling is cost reduction; and within this upscaling particularly the cost for growth medium needs to be reduced and an overall efficient production system conceptualised. A related theme that emerged is that the production of structured 3D remains a bigger long-term challenge that is technologically substantially more difficult to achieve than unstructured 2D CM products.

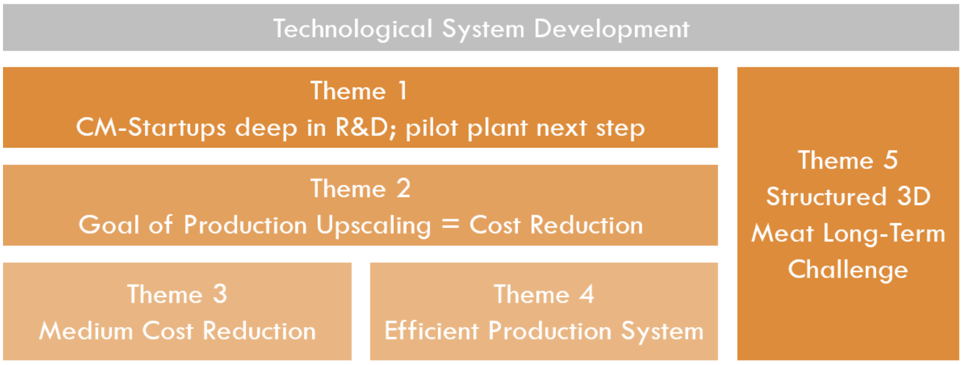

Figure 6-1: Thematic Map for Technological System Development.

Figure 6-2 summarises the themes for the supply chain. The main theme was that there currently is little work division among CM start-ups, a circumstance that restrains the effective development of the CM industry. However, first signs for a work division are emerging. A related independent theme was that CM will likely be locally produced, a viewpoint that is probably interesting to the future development of the CM industry in many ways.

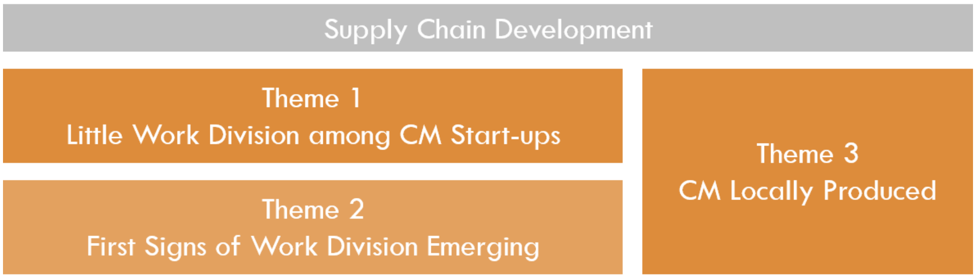

Figure 6-2: Thematic Map for Supply Chain Development.

To answer research question 3 in summary: the most important topics for the near-time development of the CM industry relate to the development of its technological system and of its supply chain. From a technology viewpoint, CM is still deeply in R&D phase, with the key challenge of reducing costs, particularly for the growth medium and the overall production system. For the supply chain, the main challenge is that there is little work division among CM start-ups, although there are first signs that this issue resolved. Further, it is likely the case that CM will be locally produced. Having presented all results, I next present the discussion.

7. Discussion

In this section, I discuss the findings of this thesis, its methodology, provide avenues for future research, summarise this thesis' contribution, provide recommendations based on the results, and conclude.

7.1. Results

Several findings from the results sections are worthwhile discussing, which is done in this section.

7.1.1. Dominant Role of the USA?

One of the most important insight from this thesis is that the USA is leading across all indicators in the CM industry, see section 5. To summarise some of the findings: US' CM firms hold more patents (section 5.1.2), are to a higher share privately funded (section 5.2.1) and received overall more investment (section 5.3.1). The only measure at which Europe is leading is public research output (section 5.1.1). One tentative interpretation of this finding is: while Europe would have from a public research perspective all the potential to become a leader in CM, it does not utilize its potential as the USA. Although the USA is substantially weaker in public research output on CM, it is substantially stronger in private research output. And what matters for the commercialisation of CM is, after all, private research output and not public research output.

However, how valid is the statement – that the USA is leading the CM industry? Although the results indicate a clear dominance of the USA, the reality is likely more nuanced. The situation is likely less decided than the results may make it appear. As indicated in the section on Entrepreneurial Activity, maybe the CM industry in Europe simply begun later. If true, we may see soon a catch-up of Europe on many important indicators, such as relative share of CM companies that received funding, or the availability of physical capital. A counterargument against this point could be that the US' current dominance may create a path dependency (Fagerberg et al., 2009) that will only even further strengthen the US' dominance in the future. Research shows that path dependency is not deterministic but that it may require considerate effort to overcome it (Hassink, 2005; Isaksen & Trippl, 2016). In other words: Europe still has the possibility to change the current pathway, if concerted action is taken. As one interviewee noted: *"To return to your question, is [the CM industry] geographically concentrated? I would say this is to be determined."*[38].

7.1.2. Technology Battle between CM and PBM?

There were several overlaps between CM and PBM mentioned in the results. As noted in the section on Public Awareness, apparently there is a spillover of the attention for PBM towards CM. And although it did not yield a theme consistent enough to be mentioned in the section on Financial Capital: Venture Capital Availability, some investors remarked in the interviews that the successful IPO of Beyond Meat spurred the investment in CM. The spillover is not surprising: both CM and PBM are, after all, meat alternatives that address potentially the same societal challenges (Chatham House, 2019; WEF, 2019a). Also the future customers for both products will likely be similar (Hartmann & Siegrist, 2017a; Slade, 2018), at least initially. Even major conferences, such as the Good Food Conference in San Francisco[39] or the New Food Conference in Berlin[40], have conference days each dedicated to CM *and* PBM. Lastly, as was indicated in the Introduction and the section on Expectations for Near-Time Development, a hybrid product between CM and PBM may be an early use case for CM cells.

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[38] Interviewee 1 (investor), [20:15]
[39] Accessible online at: https://goodfoodconference.com/; accessed 20/02/2020.
[40] Accessible online at: https://www.new-food-conference.com/; accessed 20/02/2020.

Given the apparent co-evolution or convergence of the CM and PBM spaces, the question could be raised in which relation the two technologies may stand in the future. The literature on so-called "technology battles" (or: standards wars) (Hekkert & Van den Hoed, 2004; Murmann & Frenken, 2006; Suarez, 2004) suggests that in many applications, a so-called "dominant design" emerges. For a given use case, there is an ideal solution, and this solution comes to dominate the others. For instance: there were once Blu-Ray and HD-DVD, two possible solutions for the same use case, that coexisted until Blu-Ray came to dominate the HD-DVD.

Similarly, there are different use cases for meat consumption, and one could argue it is likely that a dominant design will evolve for each over time. What exactly are these use case depends on the technological requirements underlying them. As comparison one example: a small passenger car can more easily be powered by an electric engine than a large-scale cargo ship. For meat, I suppose it is not unlikely that there is a fundamental difference between unstructured 2D meat products, such as sausage, and structured 3D meat products, such as steak. Thin structured meat products, such as bacon, are likely more similar to a 2D product than a 3D product, because they require less growth structuration (scaffolds) and likely no vascularization[41].

Assuming the two principal use cases are unstructured 2D meat products and structured 3D products, what will be respective role of CM and PBM for each? What will be the dominant design for each? In my view, there are can be made several important observations with relevance to these questions. Firstly, PBM has reached for unstructured 2D products an unprecedented degree of mimicry to conventional meat (Chatham House, 2019). According to news reports, the Impossible Burger, for example, tastes almost indistinguishable from conventional meat (T. Lewis, 2020; Samuel, 2020). If PBM can taste like real conventional meat for 2D unstructured products, the only advantage CM could play out would be if it could be cheaper or superior from a nutrition standpoint. Both aspects remain to be seen. But considering all information at the point of writing, it appears that PBM is the more likely candidate to become the dominant design for unstructured 2D meat products.

Following this logic, CM may be a better solution for structured 3D products. Although novel 3D printing technologies may enable structured 3D PBM products (Rubin, 2019), I suppose it is unlikely that they can fully emulate all 3D products. Think for instance of spareribs, chicken wings or also steak: many meat products contain bones and other components that are arguably difficult to be derived from plant sources. If CM should be the solution for this use case, the problem then is that it will likely take many years until CM can be used to produce 3D products, see the sections on Expectations for Near-Time Development and Technological System Development.

But will the CM industry survive if it cannot offer a competitive product in the mid-term, but if it requires the big breakthrough, a 3D product, to have a marketable product? As mentioned in section 6.1, creating 3D CM remains a long-term goal and appears unfeasible in the foreseeable near future. In research, the term "valley of death" (Barr et al., 2009; Wessner, 2005) describes situations in which very long R&D phases prior to market introduction starve innovations to "death", either because investors lose interest or do not have enough resources. The danger of a "valley of death" is particularly pronounced for innovations with (a) high negative cash flows respectively very high capital requirements, particularly pronounced for biotechnology, and (b) if there is uncertainty whether the innovation is actually feasible or will lead to a market success (Moran, 2007; Paul, 2008). Both factors probably apply to CM. It remains to be seen whether CM would, for instance, require governmental support to cross the "valley of death". Indeed, some interviewees noted that they think that CM may

[41] This is information I have from conversations I had at the conferences and the interviews I held.

require governmental financing to come to market, albeit again this opinion was voiced to infrequent to constitute a proper theme.

The reality will likely be more complex than the dichotomy presented here of PBM for unstructured 2D products and CM for structured 3D products. Some products fall probably somewhere in between. For example, the French specialty *foie gras*, a pâté made from duck liver, has typically a considerable amount of fat. Whether it is possible to simulate such fatty products well with PBM remains to be seen. Hence, cultivated foie gras may be more likely than plant-based foie gras, despite that it is a 2D product. Also, I mentioned already in the Introduction the possibility of hybrid products. Take a steak as example: what if the meaty part can be derived from plants, but the bone and gristle stems from cell culture? The resulting product would be a mixture between CM and PBM. Such a convergence of both spaces is clearly on possibility. I suppose it is impossible to say which of the scenarios described will be more likely. Whichever scenario will play out, this section hopefully illustrated: there will probably be a contest between CM and PBM, and both spaces will co-evolve in reaction to each other.

7.1.3. In Reality San Francisco Bay Area versus Benelux?

The comparison in this thesis was mainly done between the USA and Europe. However, in terms of entrepreneurial activity, a comparison between two other regions is maybe more sensible: between the San Francisco Bay Area and the Benelux countries. Of the eight US' focal CM companies that received funding, *seven* are based in the Bay Area, namely Finless Foods, JUST, Memphis Meats, Mission Barns, New Age Meats, Wild Earth, and Wild Type. Only one is outside, albeit still in California, BlueNalu in San Diego. Of the five European focal CM companies that received funding, two are based in the Netherlands, namely Mosa Meat and Meatable, and one in Belgium, namely Peace of Meat. The other two focal European start-ups that received funding, Bio Tech Foods and Cubique Foods, are both located in Spain, but with a far distance between them. Hence: one could argue that the real competition for entrepreneurial activity is not between the USA and Europe, but between the San Francisco Bay Area and the Benelux countries, specifically the Netherlands and Belgium.

If this view would be accepted, however, it further strengthens the observation of a stronger CM industry in the USA (in the Bay Area) than in Europe (in the Benelux countries): the Bay Area hosts approximately 8 million people (US Census Bureau, 2018) and has a GDP of about $500 billion (US Bureau of Economic Analysis, 2018); the Benelux region hosts approximately 29 million people (Statec, 2018), almost 3x times as many, and has a GDP of about $1,600 billion (IMF, 2018), more than 2x times as much. Hence, although the Benelux region is larger in population and has a substantially higher GDP, the number of CM start-ups in the Bay Area is more than twice as high. In other words: the density of CM start-ups in the Bay Area is without comparison. One could potentially even further rephrase the competition for leadership in the CM industry as one between the Bay Area and the rest of the world.

7.1.4. Cultivated Meat – A Hype?

One theme that emerged in the interview for the Expectations for Near-Time Development of CM was that there are concerns that CM is hyped, i.e. that it has too high expectations attached. This concern was mirrored in the results of the Delphi study (Tiberius et al., 2019) presented in the same section: a majority of experts anticipate that CM will at most be a niche product by 2027, without price advantage to conventional meat. In line with this, the thematic analysis also indicated that cost reduction remains a key challenge for the industry. Note in this context the order of magnitude of the cost reduction required, as noted by an interviewee: *"The pricing has to come down roughly 100,000-fold to be able to grow [cultivated] meat (…) at a large scale at a competitive price."*[42]. Yet, CM start-

[42] Quote #2 in Table 6-3.

ups often announce they will be on the market in the new few years. Given the scale of cost reduction required, and the promises CM start-ups make, albeit that experts apparently do not believe it will happen so fast, it appears a possibility that CM will not step up to its high expectations. Several supposed innovations of the past did not step up to their expectations, such as 1st generation biofuels (Hein & Leemans, 2012; A. Mohr & Raman, 2013), or specific products, such as Google Glasses (Eveleth, 2018) or Segway (Day, 2007).

One way to understand whether CM is hyped or not is to look at it through Gartner's "hype cycle" (Gartner, 2019), see Figure 7-1. Gartner, a research and polling firm, proposes that all technologies go through different phases of expectations. After the innovation got triggered, they reach a "peak of inflated expectations". Afterwards, innovations go through disillusionment, a "slope of enlightenment", and finally reach a "plateau of productivity". In the bottom left of Figure 7-1, one finds "Biotech – Cultured or Artificial Tissue", i.e. CM. Gartner proposes that CM is only at the beginning of its hype, and that the plateau will be reached in more than 10 years.

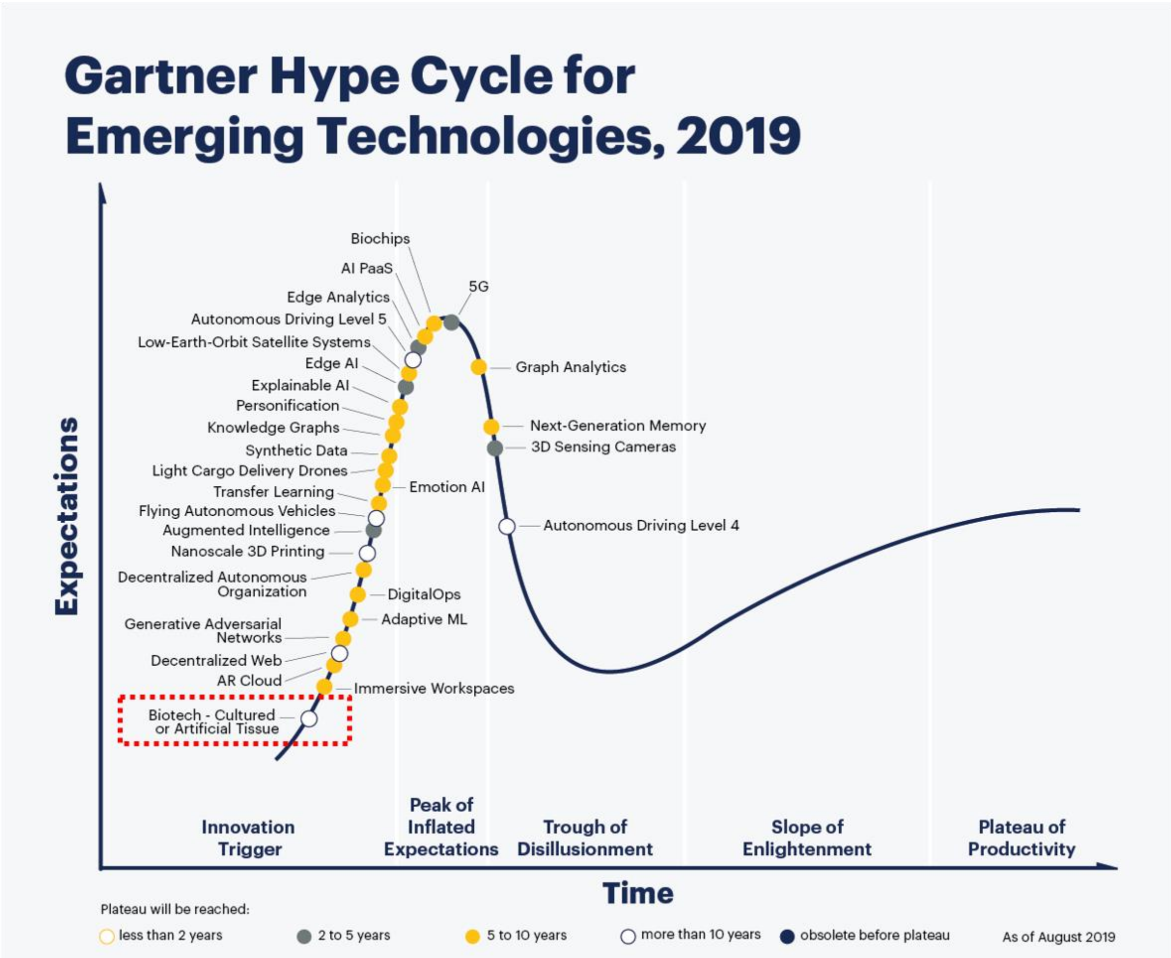

Figure 7-1: Gartner Hype Cycle 2019. © Gartner
(Adapted after Gartner, 2019)

What can we take from this? I suppose it can be argued that CM is hyped as something to be eaten within the next few years. But on the other hand, one may argue that CM is part of a megatrend bound to stay. PBM and other meat alternatives will probably only be a solution for some meat products. The need for more sustainable diets, as mentioned in the Introduction, will also only grow stronger. In other words: one could argue that independent of whether CM is currently hyped or not, it will probably in some way or another play a role in the future.

7.1.5. How will the Civil Society React?

In section 5.5.2, Reaction by the Civil Society, I showed how the civil society currently relates to CM. Essentially, this section showed that the cards are still open: it is not yet clear how the public will react to CM in detail. Currently, both positive and negative reactions are found, and none dominates.

Some in the CM industry are worried that CM may face a similar resistance by civil society actors as did GMO (e.g. Mohorčich & Reese, 2019; Splitter, 2019), see also section 2.2.4. Greenpeace, for instance, opposes GMOs still more than 20 years after their introduction (Greenpeace, 2015) with arguably an important impact on their adoption. In other words: what stance NGOs and other civil society actors, including the media, will take on CM will probably have an important impact on the CM space.

In my opinion, section 5.5.2 actually shows that the reaction by the civil society will likely not be 'arbitrary'. For instance: the interviewees noted that activist groups will only become active against CM if CM is actually bad in the activist group's area of interest (see Table 5-18, quote #3). For instance: if CM is less environmentally friendly than conventional meat, then environmental activist groups will likely become active. Overall, this can be interpreted as a positive takeaway. Although the comparison to GMOs may be perceived as a strong warning, it could be that the comparison is not granted. If CM fulfils its promises, it will clearly be a superior solution to conventional meat, while the same could not be unequivocally said for GMOs. Nonetheless, CM companies are probably still good advised to follow the learnings of the GMO debacle, such as a more transparent, less secretive communication (Mohorčich & Reese, 2019).

7.1.6. Europe – Lost Potential?

The only indicator on which Europe is clearly leading is Public Research Output. In addition, arguably the most important early research group on CM, the Mark Post group that produced the first CM burger, see section 2.2.4, is from Europe. Nonetheless, the USA is leading on almost every other measure of the CM industry. Theoretically, from a knowledge perspective, Europe has the potential to become a leader in CM. What is missing appears to be the capacity to rapidly and effectively commercialise CM. Independent of CM, it is common knowledge and widely discussed that Europe has lost edge in disruptive innovation – 'tech' – and structurally falls behind the USA and China (Delcker, 2019; McKinsey, 2019; Romei, 2019; WEF, 2019b). If Europe fails to play an important role in CM, it would yet be another point in case. However, as discussed above, the dices are not necessarily fallen yet. If European leaders decide to support CM in a structured manner, the region might catch up. I provide recommendations to support such a potential catch up below.

Next, I discuss this work's methodology.

7.2. Methodology

7.2.1. Limitations of Data Collection

For the data collection, there are four limitations. Firstly, the desk-research did not follow a structured approach. Accessible information was collected that seemed appropriate to answer the research question at hand. However, the selection of data sources was not systematic and no explicit criteria for inclusion or exclusion was applied. Data were selected alone based on their utility to answer the research question. This limitation could be resolved by following a more structured approach to the desk-research data collection. However, it may be noted that such a structured approach would be substantially more laborious, with arguably only a marginal improvement in data quality. Secondly, the quantitative data was not statistically analysed. Yet, the data sets were only not statistically analysed because they did not allow to do so. Most importantly: the sample size was too small to draw any substantial inference between the USA and Europe. This limitation could be mitigated by analysing, where possible, the available data statistically. For instance: for all data sets with continuous data, such as the share of employees per CM start-up by region, it could be analysed whether the mean difference between the groups is statistically significant[43]. Thirdly, this thesis used a high share of information from one source: the GFI. The reason why so much data by GFI was used is simply that GFI is the authority when it comes to collecting data on the CM industry. No other source, for instance, collected reliable information on the number of active CM start-ups. To resolve this limitation, one could collect more primary data, albeit this approach would be also substantially more laborious. Fourthly, the thesis did not fully exploit all possibilities to enrich the analysed indicators. For instance: I could have done an event analysis for function 5's indicator Reaction by the Civil Society, i.e. mapping positive and negative news coverage on CM (Hekkert et al., 2007). I did not further expand the used method of data collection because the limited time and resources available for this thesis. Lastly, the interviewee selection for this thesis was based on a convenience sample. I selected the interviewees based on the who I could get in touch with at the two conferences I attended. Although the resulting sample was fairly diverse, see section 3.2.1, its selection was not systematic. This limitation could be mitigated by following a structured approach for interviewee selection, for instance by writing all important people who published peer-reviewed articles on CM, all CM start-ups, etc., and selecting then in a structured way interviewees.

7.2.2. TIS as Analysis Framework

Was TIS a suitable framework to answer the research questions in this thesis? In other words: was the framework valid to conduct the analysis?

On the positive side, it appears to me that the static and functional analyses in section 4 and 5 illustrate the strength of the TIS framework: its analytical breadth. After reading through the sections, I suppose the reader has a distinct impression of the state of the CM industry in both regions. Moreover, the framework was successful in pointing out some important distinctions between the regions, for instance that Europe was leading in public research on CM.

However, on the negative side, some doubts regarding the framework can be raised. Firstly, and most importantly, the TIS framework was never quantitatively validated. Although the seven functions are the outcome of uniting previous research from various sources. In practice, the TIS framework is typically analysed with qualitative data (Hekkert & Negro, 2009), for a recent overview see e.g. Kashani & Roshani (2019) and Rakas & Hain (2019). Yet, whether the explanations provided by the TIS framework, i.e. the seven functions, are actually valid is unclear, yet the framework is used to construct narratives about why or why not an IS may evolve. There is some indication to doubt that, generally-speaking, the framework is always correct. Brenner & Murmann (2016), for instance, found in a computer simulation experiment that explanations for historic events based on qualitative data (e.g. historic narratives) are unreliable in indicating *real* causation: they analysed the development of the German dye industry 1857-1913 and found that only one of three explanations given by qualitative data was a significant predictor in the computer simulation experiment. The TIS research community is aware of this limitation and approaches for computational modelling for the framework are getting discussed (e.g. Köhler et al., 2018, 2019; Walrave & Raven, 2016). Thus, to mitigate this limitation, one possible option is to create an computational simulation model, for instance an agent-based model (e.g. Van Dam et al., 2012). Such a model could be validated on the historic development of the industry so far, although it would probably consider variables that differ from those analysed in the thesis at hand. Secondly, the static viewpoint of the TIS analysis is another limitation. In their conceptualisation of the TIS framework Hekkert et al. (2007) write that ideally a TIS analysis is *dynamic*. In other words: that a TIS tracks the development of indicators over time, and how they may interact

[43] The statistical test in this case would be an independent sample t-test or an ANOVA.

to create a certain outcome. The "cumulative causation" (Suurs & Hekkert, 2009), positive feedback loops between variables, can only be analysed with a dynamic analysis. However, a 'real' dynamic analysis is typically not possible – because it would require quasi-continuous tracking of variables. To mitigate this limitation, one could conduct the analysis at hand again in some time and see how an interaction between variables may have influenced the development of the CM industry.

Overall, these two limitations indicate that the external validity of this thesis cannot be assured. In other words: it is not clear whether the analysis carries any value to do predictions or prescriptions. For instance: although the analysis currently indicates that the USA is clearly leading, the dynamics underlying the industry's development are not clear. For this a validated, quantitative TIS model would be required. In absence of it, it could be that there are "tipping points" (Scheffer, 2010) at which the industry development drastically changes. What if, for instance, suddenly the investments in European CM start-ups grows exponentially, and it catches up with the US' start-ups in a very short period of time? Again, in absence of a validated TIS model that predicts industry development there is no way of knowing. Likewise, the analysis does not allow inferences on the degree of uncertainty of the CM industry development and the impact of future events on its fate. In other words: is it really clear that the US will dominate the industry? Based on this analysis, this inference is hardly possible, again because there is no way of knowing. Also, one cannot estimate the sensitivity of the industry to future events. How will the industry evolve differently if for instance the regulatory regime in the USA or Europe changes positively or negatively? Again, only historically validated computer simulations could allow inferences for questions as such. However, one should note that these limitations directly relate to the TIS framework and its research methodology and are not unique to this thesis.

What could be improved in the TIS framework for future analyses? As stated, above all I think the framework requires quantitative validation. However, in addition, the set of indicators to be analysed should be standardised for certain use cases. The case presented here, analysing a novel industry, is quite a conventional analysis to be done with the TIS framework. Yet, in the literature almost every author uses in detail a different set of indicators (e.g. van Welie et al., 2019; Wesche et al., 2019). This diversity in indicators used is problematic for at least two reasons. Firstly, it increases the workload for every author who applies the methodology. Secondly, it leads to a situation that two analyses applying the same TIS framework to the same use case (industry analysis) cannot be compared. Combining both points, a quantitively validated TIS framework with a (more or less) fixed set of indicators would help researchers in the future.

7.2.3. Added Value of Thematic Analysis

What value did the additional thematic analysis conducted for this thesis? Conventionally, a thematic analysis is not included in a TIS analysis (e.g. Bergek, Jacobsson, Carlsson, et al., 2008; Hekkert et al., 2011). Doing so is therefore a novel approach.

In my opinion, the thematic analysis made one important contribution: it illustrated near-time challenges from a technological standpoint. A TIS analysis entails technology in its structural analysis. Yet, technology is typically omitted from the functional analysis. As such, it typically does not become clear which factors might influence from a technological standpoint the industry in the near future. For instance: the thematic analysis revealed that there is a chance that the CM industry will be localised, see section 6.2. To the results of the TIS analysis, this is very important: if the CM industry will be localised, it weakens the impact of the advantage of the US' CM industry.

The thematic analysis could have yielded many more important points. However, the interviews for this thesis were held with a topic guide that structured the interviews, see section 3. Even though several interesting topics were mentioned in individual interviews, there was not enough data from more than one interviewee to call it a theme. I think that therefore the potential contribution of a thematic analysis is understated. If in future research the interview topic guide would be designed to incorporate more open sections that match the logic of the thematic analysis, it may proof even more useful. Overall, I consider the thematic analysis a valuable contribution.

Why did the thematic analysis yield the themes it yielded? I think there are two reasons. Firstly, as mentioned, the topic guide was not sufficiently open, so only the most important themes could have evolved from it. But secondly: I think the themes that evolved are actually simply the most important themes for the near-time development of the industry. In other words: I do not think that it was coincidence that precisely these two themes evolved. The themes evolved because they are important in the current state (Markard, 2020) of CM's TIS.

Next, I explore avenues for future research.

7.3. Future Research

There are at least three routes to extend the results at hand in the future. Firstly, the analysis could be extended to other theoretical frameworks. For instance, the analysis could be extended by a MLP analysis (Geels, 2005), discussing macro factors that shape the development of the CM industry. Also, one could use the SNM framework (Raven et al., 2010) to understand in more detail the processes that occur within the CM start-up scene (niche) in various regions. Secondly, one could extend the industry at hand to other regions. Most importantly, it would worthwhile to extend the analysis to Israel, another key region of the CM industry. The Asia-Pacific region is arguably less fit to an analysis of this sort, because the CM developments there are still very geographically fragmented compared to the USA, Europe or Israel. Moreover, CM-related activities in one Asian-Pacific country, such as China, cannot be easily linked to that in another country, for instance Singapore. Asia-Pacific is compared to the EU no political or economic union, and it is unlikely that the IS there is integrated as in Europe. Thirdly, one could take forward one of suggestions made Methodology discussion improve the work at hand. In my viewpoint, the most important one would be a validation of the results with a computational simulation.

The next section summarises this thesis' contribution.

7.4. Contribution

The contribution of this work is twofold. From an empirical perspective – with relevance to practitioners - it adds to an understanding of the CM industry and how it may differ by region. The assessment benefits the industry itself and governments of countries that are hosting CM companies. To the CM industry, an understanding of its own dynamics allows to increase its degree of coordination, e.g. by aligning on common visions and goals, establishing strong lobby organisations, and agree on technological standards. Coordinated industries help their firms to gain comparative advantage against competing industries (e.g. Hess, 2016; Suarez, 2004). Hence: a coordinated CM industry may experience for instance a faster speed-to-market and higher competitiveness versus conventional – less sustainable – meat products. To governments, an understanding of the CM industry can inform industrial policy, for instance the design of schemes to support the CM industry in their respective region. Favourable conditions and a well-connected network of stakeholders – clusters – provide companies with a comparative advantage (Broekel et al., 2015; Lee, 2018; Libaers & Meyer, 2011), too. Accordingly, policymakers may be interested in making informed decisions to strengthen their local CM industry. I summarise Recommendations to both aspects in the next section.

For theory, this thesis makes three contributions. Firstly, it adds an empirical example of an international TIS analysis; respectively of a comparative TIS. Empirical applications of TIS tend to be limited to singular case studies. By conducting an international comparative case study using TIS in a structured manner, this thesis may inform future research that seeks to do the same. Secondly, this thesis provides an application of recent updates of the TIS function positive externalities. Since the inception of the TIS framework, two competing formulations, one by Hekkert et al. (2007), one by Bergek et al. (2008), existed. The difference between both frameworks lays in one aspect to be analysed: positive externalities. Positive externalities (or: positive spill-overs) exist when companies benefit from the existence and activities of other neighbouring companies and actors (Bergek, Jacobsson, & Sandén, 2008). Different causes for positive externalities can existing – one of the most important is knowledge spill-overs between companies, for instance through workforce pooling. Positive externalities are often based on network effects: the value of a network potentiates as the number of network actors increases (Katz & Shapiro, 1994). The outcome of positive externalities are external economies of scale (R. D. Mohr, 2002): individual companies located in a place where positive externalities are apparent, i.e. in a cluster, have lower average costs than those located outside of the cluster. Recent papers emphasised the importance of positive externalities (Bergek et al., 2015; van Welie et al., 2019). For instance: TIS may get influenced from spill-overs from neighbouring sectors (Bergek et al., 2015). In the CM case that would mean to for instance consider links to the biotechnology sector in total. By re-applying the function positive externalities based on recent literature, this thesis hopefully helped future researchers to give better justice to that function. Thirdly, this thesis extended the conventional data analysis of the TIS framework by a thematic analysis. By doing so, it makes the analysis more flexible and open to incorporating not anticipated information. Overall, I suppose that a thematic analysis increases the external validity of a TIS analysis and is therefore a useful complementation.

In this next section, recommendations based on this thesis are provided.

7.5. Recommendations

7.5.1. Recommendations to Policymakers

What recommendations can be given to policymakers in the USA or Europe who want to strengthen the CM industry in their region? To advise policymakers, the functional analysis provides specific input. On a general level, independent of regions, it appears that CM is lacking funding for public research, see section 5.3.2. Specifically, grants to support laboratories to switch from well-funded research initiatives in biomedical applications to CM and stipends for PhDs student in CM are missing. In addition, a region-unspecific recommendation is potentially to prepare funds to help CM over a "valley of death". In case there is a lack of funding for CM in the near future, particularly to build larger commercial plants, governments could help the industry.

For the specific regions, advises can be deduced from the results of the functional analysis. For the USA, the picture looks promising. However, on a detail level it appears that the regulation could be clearer. Particularly, there appears a threat of manipulation by the lobby of meat incumbents, see section 5.5.1. US policymakers could try to make the regulatory process waterproof against influence from the conventional meat sector. Also, the regulatory process in case CM contains GMOs is not entirely clear. Whether CM is generally considered to be safe (GRAS) remains to be seen – but it would be useful to know the exact approval pathways in case CM is not.

For Europe, there are many avenues for recommendations for governmental support. I want to focus on specific suggestions. Firstly, Europe is missing apparently scientific co-founders for CM start-ups, see section 5.3.3. Yet, Europe is also leading in public research output on CM, see section 5.1.1. The issue is, as one interviewee noted, that European scientists are apparently more risk-averse than their American counterparts. To a European scientist it is arguably more unusual to leave university and go to the start-up world than it is to an American researcher. My suggestion is that the European Commission, or national governments, create a stipend for researchers who pause their university position to co-found a CM start-up. The grants could be tied to guaranteed re-employment in case of start-up failure and pay a share of the salary for some years ahead. Secondly, it appears Europe is missing early-stage financing for CM, see section 5.3.1, and infrastructure for the early stage, see section 5.3.4. My suggestion is that the European Commission or a national government creates an incubator aimed at CM and, to diversify the risk, at the cellular agriculture in more general. Such an incubator could be associated for example with the European Institute of Innovation & Technology (EIT) Food[44], an independent EU body. Thirdly, Europe could even further clarify the regulatory approval process. While the regulatory pathway for a CM *not* containing GMO is relatively clear, it is much less so if CM contains GMOs. Although theoretically there is a regulatory pathway for the approval of GMOs, it was designed for *crops*, not for food. Accordingly, it is unclear how exactly the regulatory framework can be applied to CM. One example: what, in the definition of a "GMO" as an organism, is really a GMO in CM? If genetic engineering is used for CM, it is used to manipulate cells even before the constitute an organism. And if it is used, the resulting cells are biologically and chemically identical to cells found in nature. In other words: even "GMO" cells for CM could be called "natural". The GMO legislation in Europe poses the biggest threat to its market adoption, also because it could cross-fertilise concerns towards CM, see section 5.7. If European governments would like their local CM industry to succeed, they are advised to make the regulatory framework not more difficult than it is in other, competing regions. If not, Europe may eventually be again an importer of CM produced elsewhere, as it is the case with GMOs and many other tech innovations now.

7.5.2. Recommendations to CM Companies

For (future) founders of CM start-ups, two recommendations can be given. Firstly, concerning siting decisions. In case a founder is completely agnostic about the location to start a CM company, the results indicate the USA as an obvious choice, particularly the San Francisco Bay Area. No other region arguably offers as many positive externalities. The region is leading in entrepreneurial activity (see section 5.2), related private research output (see section 5.1.2), and is home to one of the world's strongest biotechnology clusters (see section 5.4.2). However, a counterargument is that it is better to be a big fish in a small pot than the reverse. Also, overall costs will be substantially cheaper in almost any region other than the Bay Area. I suggest a two-way approach: potential founders could attend an incubator and possibly subsequently an accelerator in the USA, and afterwards move to their final site elsewhere in the world. This way, aspiring CM entrepreneurs could benefit from all the knowledge spill overs that likely exist in the Bay Area, and subsequently benefit from lower costs elsewhere. It should be noted, however, that knowledge spill overs are not bound to regions. If an aspiring CM founder worked beforehand at an existing CM company or associations, such as GFI, it might have the same benefit as working in the Bay Area for a while. Secondly, concerning the role in the CM supply chain. As indicated in section on Supply Chain Development, it was argued by interviewees that a work division in the industry needs to emerge and that also first signs of it are already visible. Moreover, the older CM start-ups, such as Mosa Meat or Memphis Meats, have already several years advantage compared to a potential new start-up. In addition, they have acquired quite substantial investments, in the case of Memphis Meats about $181 million, see section 5.2.1. The recommendation for new CM start-ups then is to focus on a very specific niche in the CM supply chain. Probably the seats for the focal CM companies, the future brand companies, are already taken. Examples of other niches are bioreactor design, scaffold development, or the upscaling of the medium production. Arguably the technological challenges for CM will move now evermore from science to engineering. It will probably be particularly fruitful to transfer knowledge from the manufacturing in neighbouring industry,

[44] Accessible online at: https://www.eitfood.eu/; accessed 20/02/2020.

particularly the pharmaceutical industry, the fermentation-using food industry (e.g. breweries) and the meat processing industry to CM.

The next section gives the overall conclusion of this thesis.

7.6. Overall Conclusion

The main research question of this work was: *what is the status of the cultivated meat industry in the USA and Europe?* To answer this research question, I conducted extensive desk-research, summarising existing data, and interviewed 21 cultivated meat (CM) experts. I analysed the data through the lens of a technological innovation system (TIS), a framework often used to analyse emerging industries. Specifically, I applied three analyses: a structural analysis, a functional analysis, and a thematic analysis. In the structural analysis, I sought to provide an overview of the CM technology, actors and actor networks associated with it, and institutions in which it is embedded, most importantly its regulation. In the functional analysis, I analysed in detail a wide array of indicators to comparatively understand the CM industry in the USA and Europe. Particularly, seven functions of the TIS framework were analysed. The main takeaway from this analysis is that the USA is leading on every single indicator analysed, for instance entrepreneurial activity, funding availability or entrepreneurial ecosystem strength. The only exemption was public research output related to CM, which is stronger in Europe. In the thematic analysis, I deduced what key challenges the CM industry is facing according to the interviewees. The two main themes that were identified are the development of the technological system and of the supply chain. While for the technology reducing cost appears the most important topic ahead, for the supply chain developing a work division among CM companies appears the biggest issue. Overall, the CM industry is growing in both regions strongly. The CM industry appears currently consistently stronger in the USA, but it remains to be seen whether this current edge can be translated in a long-term advantage.

Appendices

Appendix A. Interview Procedure and Topic Guide

At the beginning of the interview, the participants were informed about what the interview would entail, how their data would be used and stored, and how their data would be anonymously processed. Afterwards, they would be asked for their informed consent. All interviews were recorded, and each interview received a running number (e.g. "interviewee 1") to allow disassociation from the interviewee.

Table 0-1 shows the topic guide for the interviews. The topic guide was written to span an arc from the general to the specific. For interviews that yield high data quality establishing a relationship with the interviewee is required (Marinkovic & Lee, 2017). The arc-spanning topic guide should mirror the structure of a regular conversation, supporting the creation of a positive relationship with the interviewee. In addition, preliminary interviews indicated that it was important to see what the real expertise of an interviewee was: otherwise they would just give their thought to whatever I ask, without necessarily revealing their area of expertise. For this reason, I asked at the beginning the general views on the CM industry. By asking broad and general questions, I sought that participants mention what they deem themselves most important. In other words: that they demonstrate by self-selection their area of expertise. After the general part, I guided the interviews towards more specific questions about the interviewee's area of expertise, i.e. specific TIS functions. If appropriate, the questions were phrased to draw a comparison between the assessed regions. Because each interview varied widely and were tied to each specific interviewee, the topic guide can be seen as a 'menu' from which the most relevant questions were used, if needed – taking the common introduction aside.

Table 0-1: Topic Guide.

Theme	Topic	Sub-Topic	Questions/Content
0. Prior to Interview			▪ Ideally inform participants about what research will entail and the TIS functions you look at
1. Introduction	Welcoming		▪ Welcoming participants ▪ Short small talk
	Consent		▪ Informing participants about consent ▪ Asking for their consent
2. General TIS Comparison	General State of TIS		▪ In your impression, what is the current state of the CM industry? ▪ What factors are in your perception holding the CM industry back? ▪ What will be in your perception be the main issues for the industry in the upcoming months and years?
	Strongest TIS		▪ What, in your perception, in which country the CM industry and research activity is the strongest? ▪ Why do you think this is the case?
	Comparison		▪ You just mentioned XYZ hosts the strongest CM industry and research activity. How do you think USA/Europe compares to that? ▪ Why do you think USA/Europe is performing worse? ▪ What regions specifically in the USA/Europe do you think is performing stronger?
	Area of expertise / transition to the specific		▪ "Now I would like to speak more specifically about your area of expertise" ▪ Ask participants for their touch points with cultivated meat so far ▪ Describe participants the type of research you're doing: 360° overview of CM industry and research – particularly comparing USA to Europe ▪ Ask participants to describe what TIS function they think they are most knowledgeable
3. Function Analysis (deciding on 1-3 based on experts' expertise)	Knowledge Development and Diffusion	Public research output	▪ At which institutions or research group do you think the most important research for CM is being conducted? ▪ Are there any researchers you would like to point out that do important research on CM? ▪ The medium cost appear to be particularly a topic currently. Do you have any thoughts where most important research on that area is being done? ▪ CM is an application of biotechnology. Do you know any regions that are specifically strong in that area? ▪ Can you name reasons from your perception why the public research output might be different between the regions?

	Private Research Output	▪ Which CM company does in your opinion conduct cutting edge research? ▪ Are you aware of any CM start-up particularly ahead of the competition, based on the patents they filed? ▪ Do you have an opinion on why the research output on CM might differ by each CM company?
	Knowledge Exchanges	▪ What are in your opinion the most important conferences on CM? ▪ Are you aware of any important localised knowledge exchanges on CM that might not be big in the press? ▪ Can you name any organisations or individuals who are driving forces behind knowledge exchange in CM? ▪ Why do you think the knowledge exchanges might differ by region?
Entrepreneurial Activity		▪ What are in your opinion the most promising CM start-ups? ▪ Are there any CM start-up founder who in your opinion stand out? ▪ Why do you think does the entrepreneurial activity in CM differ by region?
Resource Mobilisation	Financial Capital: Venture Capital Availability	▪ In which region it is easiest to get access to venture capital to start a CM company? ▪ What do you think accounts for the differences in venture capital availability between the regions? ▪ Why are there more venture capital firms in some region than in another?
	Financial Capital: Research Funding Availability	▪ Are there any region-specific research grants or funds for CM available you are aware of? ▪ Why do you think there are not more public research funds available? ▪ What could in your opinion be done to support researchers active in the field?
	Human Capital Availability	▪ Do you think CM start-ups have easier access to very good graduates in relevant fields, e.g. tissue engineering, in certain areas over others? ▪ Why do you think there are more graduates available by different regions? ▪ What could universities do to prepare graduates better for the CM space?
	Physical Capital and Supportive Infrastructure	▪ Where do you think CM start-ups have the easiest access to labs and other required physical infrastructure? ▪ Why do you think it is easier for CM start-ups to get access to labs and other infrastructure in certain regions? ▪ What could be done in your opinion to increase the accessibility to physical infrastructure for CM companies?
Positive Externalities	Entrepreneurial Ecosystem Strength	▪ Which region is in your opinion generally speaking best prepared to support CM start-ups? ▪ Do you think a CM start-up will have a significant difference in difficulty to start-up in one region over another? ▪ Are there any particular ecosystem factors that are in your opinion important to support CM start-ups?
	Biotechnology Sector Strength	▪ Which region is in your opinion generally speaking strongest in the sectors relevant to CM, i.e. biotechnology, particularly red biotechnology? ▪ Can you name any reasons why the relevant sectors might be stronger in one area over the other? ▪ What role does in your opinion the support by a strong sector play for a CM start-up?
Legitimation	Lobbying Activity	▪ Are there any organisations that do lobbying for or against CM existent to your knowledge? ▪ Are there any regional differences in the lobbying for or against CM existent? ▪ Why do you think there are regional differences in the lobbying activities?
	Reaction by the Civil Society	▪ How does the civil society – newspapers etc – react to CM in your view? ▪ Does the civil society react differently by region? ▪ Why do you think the civil society reacts differently in each region?
Search Guidance	Expectations for Near-Time Development	▪ How do you think CM will develop in the next 10 years? ▪ What do you think other stakeholders think it will develop in the next 10 years? ▪ What are in your opinion the most important issues that will decide on CM's development in the next 10 years?
	Public Awareness	▪ Do you have an opinion whether CM is better or worse received in any of the regions? ▪ Why do you think the public reacts differently to CM in the different regions? ▪ What could be done to draw a more positive picture of CM in the different regions?
Market Formation	Consumer Acceptance	▪ Why do you think people in certain regions are more likely to try CM, for instance in the US? ▪ Which factors could in your opinion most positively influence consumer acceptance by region? ▪ Do you think CM will diffuse to the mass market more easily in a certain geography?
	Regulation	▪ How easy do you think it will be to receive regulatory approval for CM? ▪ How long do you think it will take to receive regulatory approval for CM? ▪ Do you think the regulatory approval process will be political?

4. Closing / Debriefing	▪ Thank for participation ▪ Inform that you will get in touch with them if/when results are published

Appendix B. Rationale for Stakeholder Analysis

Table 0-2 shows the rationale for the categorisation of actor groups along the power and interest variables, as displayed in Figure 4-2.

Table 0-2: Explanation for Actor Group's Power and Interest Categorisation.

Actor Group	Power	Interest
CM interest groups	Low: The CM interest groups entail so far a very limited number of actors with likely a low funding compared to other interest groups. For this reason, their effectivity in lobbying for instance for a certain regulation is likely limited.	High: Naturally, the CM interest groups are very much interested in the CM industry.
Farmer's interest groups	Medium: First of all, the power of farmer's interest groups varies by country. For instance: in France and partly Germany they are traditionally very strong, in other countries weaker. However, I chose to assign them nonetheless only medium power because their influence on high-tech policy is likely limited. In other words: they can likely slow the process down and throw some stones in the way, but they can't stop it entirely.	Low: In some countries the farmer's interest groups are growing in their interest in CM. However, overall there is not yet for instance a broad opposition by farmer's lobbies against CM. I suppose CM is until now too small to get so much attention from them.
Incumbent meat producers	Medium: Large meat producers are big corporates and have for this reason typically very high budgets under their control – that can be used to influence policymakers, buy key IP of CM to block the industry, etc. However, money can bring you only so far and the meat industry cannot directly influence whether the CM industry will continue to grow, or not.	Medium: Some meat producers show already a very high interest in the CM industry, for instance Tyson. However, there is also a high number of meat producers that show no interest in CM whatsoever so far. Hence, overall it appears there is only a medium interest in the CM industry so far, on average.
Investors	High: Without financial investment there cannot be a CM industry. Investment by state authorities is existing but cannot substitute the private investments that are possible in the VC model. For this reason, the power of investors to influence the fate of the CM industry is high.	High: Investors in CM naturally have a high interest in CM. However, note that this actor group is limited to investors in CM. Not *all* investors have a high interest in CM.
Media and activist groups	High: Civil society actors shape the public opinion, and thereby will also shape the reception of CM. The case of GMO rejection in Europe illustrates how high the power of civil society actors is, see Mohorčich & Reese (2019).	Low: Most civil society actors are so far merely observing CM relatively dispassionately. There is for instance no regular reporting on CM in major newspapers so far. Only some articles in non-niche newspapers are getting released, e.g. Corbyn (2020). Also activist groups have not really caught up on CM yet, and only very few explicit opposition (e.g. Friends of the Earth, 2018) or support was voiced so far. Most activist group remain neutral so far.
Regulatory authorities	High: Regulatory authorities will decide whether and how CM is introduced in the market. Hence: they have direct influence over the fate of the CM industry. It should be noted, however, that this influence is rather local than global, and rather temporarily than ongoing. Some regulatory authorities will most likely allow CM (given that CM is safe), and then it is only a question of time until other regions follow suit.	Medium: Regulatory authorities only become active once someone applies to go through the regulatory process. Hence, although the authorities have an intrinsic interest in the space, they do not have high interest in the field unless they need to become active, which they do not need to yet entirely.
Start-ups	High: Without CM start-ups there will not be a CM industry. Hence, the start-ups have very high power in influencing the CM industry: they are their key actor group.	High: Naturally, CM start-ups have a strong interesting in the CM industry.
Suppliers	Low: Suppliers have currently low power over the CM industry because the industry is not yet dependent on them. The CM industry requires obviously some inputs from suppliers (e.g. culture media, bioreactors) but it is not that for instance suppliers exert influence on the CM industry through power in price negotiations. The power of suppliers might change in the future.	Low: The market CM companies comprise for supplier companies at this point in time is very limited. Some suppliers show high interest in CM and are frequently for instance visible on the industry's exhibitions, for instance the Merck Group. However, one cannot say that there is a broad interest in the CM space by potential suppliers yet – the industry is too nascent.
Supporting NGOs	Medium: The supporting NGOs, particularly the Good Food Institute and New Harvest, are a key player in the CM industry. They not only facilitate some of the industry's most important knowledge exchanges, but also finance research on it. However, in the grand scheme of things these NGOs are on comparison to	High: The NGOs in this actor group are either exclusively or strongly interested in the CM space. They have therefore a high interest in the space.

	for instance entrepreneurial firms and investors rather peripheral actors. Hence: they have influence on the CM industry, yes, but their power is unlikely to be very high.	
Universities	Low: As explained in section 5.1.1, is the public research on CM still limited. Private research on CM is considered more advanced than the public research. For this reason, I chose to categorise universities to have low power. It appears, state now, that the research in these institutes will have some influence on the fate of the CM industry, but arguably not a very strong one.	Medium: Some university researchers have a very strong interest in the CM space, while others have little. On average, it appears one can speak of medium interest from universities, on average.

Appendix C. Methodological Notes on Bibliometric Publication Analysis

The bibliometric analysis of section 5.1.1 was conducted using Scopus[45], a publication search engine of Elsevier. A registration is necessary to conduct searches using Scopus. The following filters were applied:

- Published between 2007 and 2019
- English language
- Carrying in title, abstract or keywords an exact match for "cultivated meat" or seven synonyms, namely "cultured meat", "cell-based meat", "in-vitro meat", "clean meat", "lab-grown meat", "synthetic meat" and "slaughter-free meat"
- Limited to publications in the fields of science, technology, engineering and mathematics (STEM), because of special relevance to CM
- Not limits were set on the type of publications; hence, the bibliometric analysis includes also trade publications

The total query was:

> (TITLE-ABS-KEY("cultured meat" OR "cultivated meat" OR "cell-based meat" OR "in-vitro meat" OR "clean meat" OR "lab-grown meat" OR "synthetic meat" OR "slaughter-free meat") AND (LIMIT-TO (LANGUAGE,"English")) AND (LIMIT-TO (SUBJAREA,"AGRI") OR LIMIT-TO (SUBJAREA,"BIOC") OR LIMIT-TO (SUBJAREA,"ENVI") OR LIMIT-TO (SUBJAREA,"ENGI") OR LIMIT-TO (SUBJAREA,"MEDI") OR LIMIT-TO (SUBJAREA,"VETE") OR LIMIT-TO (SUBJAREA,"CENG") OR LIMIT-TO (SUBJAREA,"CHEM") OR LIMIT-TO (SUBJAREA,"MULT") OR LIMIT-TO (SUBJAREA,"IMMU") OR LIMIT-TO (SUBJAREA,"COMP") OR LIMIT-TO (SUBJAREA,"ENER") OR LIMIT-TO (SUBJAREA,"MATE") OR LIMIT-TO (SUBJAREA,"EART") OR LIMIT-TO (SUBJAREA,"MATH") OR LIMIT-TO (SUBJAREA,"NEUR") OR LIMIT-TO (SUBJAREA,"PHAR") OR LIMIT-TO (SUBJAREA,"PHYS")))

The publication date limitation was set via manual filter selection in the "Analyse search results" section of Scopus. After the query, the results were exported as .CSV and analysed using Microsoft Excel.

For the analysing the geographical distribution split, as showed in Figure 5-2, the countries were allocated one of the seven regions visible in the graph (Europe, USA, Asia-Pacific, Other, Latin America, Canada, and Israel).

For analysing the affiliation, as summarised in Table 5-1, the initial data list was cleansed. The same research organisations with different spellings were collapsed (e.g. "University of XY" and "XY University") and wrong affiliations removed (e.g. the data entry "Centre for Genetics", without

[45] Accessible online at: www.scopus.com

mentioning to which institution this centre belonged). The initial number of affiliations were 160, after data cleansing the mentioned 150 remained.

Appendix D. Methodological Notes on Patent Analysis

The patent analysis was conducted on the databases Patentscope and Depatisnet. The two databases index the same data, and I used both only to ensure data quality through a theoretically redundant search. In addition, I cross-checked my own results with available publication analyses from stakeholders in the CM space[46].

My searches were limited to patents directly relatable to CM, i.e. not for instance patents from stem cell research that are somehow relevant to CM. Further the search as limited to patents that are either active or pending, i.e. patent applications. Expired or rejected patent applications were excluded. To allow consistency with the publication analysis, I excluded patents before 2007, although this concerned only two patents. As date I took the date of application (priority date) and allocated the patents to regions based on the location of the organisations to which they belong.

For patentscope, the following query was used:

> FP:("cultured meat" OR "cultivated meat" OR "cell-based meat" OR "in-vitro meat" OR "clean meat" OR "lab-grown meat" OR "synthetic meat" OR "slaughter-free meat")

For Depatisnet, the following query was used:

> Search query: TI = ("cultured meat" OR "cultivated meat" OR "cell#based meat" OR "in#vitro meat" OR "clean meat" OR "lab#grown meat" OR "synthetic meat" OR "slaughter#free meat") OR AB = ("cultured meat" OR "cultivated meat" OR "cell#based meat" OR "in#vitro meat" OR "clean meat" OR "lab#grown meat" OR "synthetic meat" OR "slaughter#free meat") OR CL = ("cultured meat" OR "cultivated meat" OR "cell#based meat" OR "in#vitro meat" OR "clean meat" OR "lab#grown meat" OR "synthetic meat" OR "slaughter#free meat")

The whole list of patents that was found can be seen in Table 0-3.

Table 0-3: List of Patents.

Title	Application Date	Identifier	Associated Organisation	Region
Cultured Meat Compositions	11/07/2016	WO2019016795A1	Aleph Farms	Israel
Methods for large scale generation of stem cells	24/08/2018	WO2015008275A1	Aleph Farms	Israel
Synthetic Meat	02/05/2016	US20170253849A1	Empire Technology Development	USA
Systems and methods for growing cells in vitro	30/10/2013	WO2018011805A9	Future Meat	Israel
Large scale cell culture system for making meat and associated products	14/01/2016	US20190376026A1	Fork and Goode	USA
Growth guidance system, growth induction controller, growth guidance control method, and the growth induction control program	06/05/2017	JP6111510B1	Integriculture	Asia-Pacific
Method for scalable skeletal muscle lineage specification and cultivation	13/07/2017	US20160227830A1	Memphis Meats	USA
Methods for extending the replicative capacity of somatic cells during an ex vivo cultivation process	26/07/2011	WO2017124100A1	Memphis Meats	USA
Compositions and methods for increasing the culture density of a cellular biomass within a cultivation infrastructure	26/07/2012	WO2018208628A1	Memphis Meats	USA
Compositions and methods for increasing the efficiency of cell cultures used for food production	07/09/2012	WO2019014652A1	Memphis Meats	USA
Engineered comestible meat	09/01/2013	US8703216B2	Modern Meadow	USA
Dried food products formed from cultured muscle cells	13/09/2013	US20160227831A1	Modern Meadow	USA

[46] Available online at: https://www.culturedabundance.com/; accessed 24/01/2020

Spherical multicellular aggregates with endogenous extracellular matrix	03/05/2018	WO2014039938A1	Modern Meadow	USA
Methods and devices for preparing and continuously printing multicellular cylinders onto biocompatible substrates	09/04/2017	WO2014110250A1	Modern Meadow	USA
Edible and animal-product-free microcarriers for engineered meat	07/06/2017	US20150079238A1	Modern Meadow	USA
Apparatus and process for production of tissue from cells	08/10/2016	US20190338232A1	Mosa Meat	Europe
Cultured meat-containing hybrid food	24/11/2016	WO2018189738A1	Super Meat	Israel
Ex vivo meat production	11/07/2016	WO2018227016A1	Wild Type	USA
Method of producing edible cell	24/08/2018	WO2018064968A1	Unclear	Asia-Pacific
Controllable transcription	02/05/2016	WO2018096343A1	Meatable (not sure, but attributed)	Europe

Appendix E. Methodological Notes on Knowledge Exchange

I collected information on conferences that are to a big share, mainly or exclusively focused on CM. Also, only international conferences were included, i.e. conferences exclusively in local languages excluded. The keywords used for the online search were such as "cultured meat conferences 2018", using various synonyms for CM.

Table 0-4 entails the full list of conferences considered for section 5.1.3.

Table 0-4: List of Conferences.

Conference Name	Host	Year	Volume	Region
International Scientific Conference on Cultured Meat	Mosa Meat / Maastricht University	2015	1	Europe
International Scientific Conference on Cultured Meat	Mosa Meat / Maastricht University	2016	2	Europe
International Scientific Conference on Cultured Meat	Mosa Meat / Maastricht University	2017	3	Europe
International Scientific Conference on Cultured Meat	Mosa Meat / Maastricht University	2018	4	Europe
International Scientific Conference on Cultured Meat	Mosa Meat / Maastricht University	2019	5	Europe
Good Food Conference	GFI	2018	1	USA
Good Food Conference	GFI	2019	2	USA
New Harvest Conference	New Harvest	2016	1	USA
New Harvest Conference	New Harvest	2017	2	USA
New Harvest Conference	New Harvest	2018	3	USA
New Harvest Conference	New Harvest	2019	4	USA
Cultured Meat Symposium	Cultured Meat Symposium	2018	1	USA
Cultured Meat Symposium	Cultured Meat Symposium	2019	2	USA
Future Meating	Modern Agriculture Foundation	2017	1	Israel
New Food Conference	ProVeg	2018	1	Europe
New Food Conference	ProVeg	2019	2	Europe
Industrializing Cell-Based Meat Summit	Hanson Wade	2019	1	USA
Cultivate	Cultivate-UK	2016	1	Europe
Cultivate	Cultivate-UK	2017	2	Europe
Cultivate	Cultivate-UK	2018	3	Europe
Cultivate	Cultivate-UK	2019	4	Europe

Appendix F. Full List of Cultivated Meat Companies

Table 0-5 lists all CM companies used in the analysis.

Table 0-5: List of CM Companies.

Company Name	Region	Year Founded	Focal vs. Supplier[1]	In Top 50 Start-up City?	Estimated Investment Received[2]	Estimated Number of Employees[3]
Artemys Foods	USA	2019	Focal	Yes	N/A	2
Cell Farm Food Tech	Latin America	2019	Focal	No	N/A	1
Mirai Foods AG (fmr. AlphaMeats)	Europe	2019	Focal	No	N/A	2
Vow Food	Asia-Pacific	2019	Focal	No	N/A	8
Heuros	Asia-Pacific	2017	Focal	No	N/A	1
Multus Media	Europe	2019	Supplier	Yes	N/A	9

Bio Tech Foods	Europe	2017	Focal	No	2.4	8
SeaFuture	Canada	2017	Focal	No	0	2
Future Fields	Canada	2017	Supplier	No	0	3
Appleton Meats	Canada	2016	Focal	Yes	0	1
Avant Meats	Asia-Pacific	2018	Focal	Yes	0	3
Gourmey (fmr. Supreme)	Europe	2019	Focal	Yes	0	12
Innocent Meat	Europe	2018	Focal	No	0	3
Clear Meat	Asia-Pacific	2018	Focal	Yes	0	3
BioFood Systems	Israel	2018	Focal	No	0	2
Future Meat Technologies	Israel	2017	Focal	No	16.2	11
Aleph Farms	Israel	2016	Focal	No	14.4	19
SuperMeat	Israel	2015	Focal	Yes	4.2	8
Integriculture	Asia-Pacific	2015	Focal	Yes	2.749	4
Meatable	Europe	2018	Focal	No	13.5	20
Mosa Meat	Europe	2015	Focal	No	7.5	37
Shiok Meats	Asia-Pacific	2018	Focal	Yes	4.8	13
Cubiq Foods	Europe	2018	Focal	No	12	10
Biftek	Europe	2018	Supplier	No	0	4
Higher Steaks	Europe	2018	Focal	Yes	0.015	8
Balletic Foods	USA	2017	Focal	Yes	0	0
Fork & Goode	USA	2018	Focal	Yes	0	5
Mission Barns	USA	2018	Focal	Yes	3.5	12
New Age Meats	USA	2018	Focal	Yes	3	6
BlueNalu	USA	2017	Focal	Yes	24.5	20
Wild Earth (clean meat aspect of business)	USA	2017	Focal	No	1.22	2
Wild Type	USA	2017	Focal	Yes	16	16
Finless Foods	USA	2016	Focal	Yes	3.5	18
Memphis Meats	USA	2015	Focal	No	181.1	58
JUST (clean meat aspect of business)	USA	2011	Focal	Yes	22	15
Lab Farm Foods	USA	2019	Focal	Yes	0	2
Alife	Europe	2019	Focal	No	N/A	4
Cell Ag Tech	Canada	2018	Focal	Yes	0	4
MeaTech	Israel	2019	Focal	No	0	3
Planetary Foods	Europe	2019	Focal	Yes	N/A	2
TurtleTree Labs	Asia-Pacific	2019	Supplier	Yes	0	8
Back of the Yards Algae Sciences (part of a larger business)	USA	2018	Supplier	Yes	0	5
Incuvers (part of a larger business)	Canada	2018	Supplier	No	0	8
SunP Biotech (part of a larger business)	USA	2014	Supplier	No	4.3	13
Because Animals	USA	2019	Focal	Yes	0	7
Cultured Blood	Europe	2019	Supplier	No	N/A	3
Biomimetic Solutions (part of a larger business)	Latin America	2017	Supplier	No	0.1	6
Atlast Food Co	USA	2019	Supplier	Yes	N/A	0
Agulos Biotech (part of a larger business)	USA	2017	Supplier	No	N/A	3
Macánta Meats	Europe	2019	Focal	No	N/A	1
Matrix Meats	USA	2019	Supplier	No	N/A	1
Cellular Agriculture Ltd.	Europe	2016	Focal	No	N/A	2
Ospin Modular Bioprocessing (part of a larger business)	Europe	2014	Supplier	Yes	0	12
Celltainer Biotech BV	Europe	2015	Supplier	No	0	1
Biocellion (part of a larger business)	USA	2013	Supplier	Yes	N/A	4
Luyef Biotechnologies	Latin America	2019	Supplier	No	N/A	3
Peace of Meat	Europe	2019	Focal	No	4.3	6
ArtMeat	Asia-Pacific	2019	Focal	No	N/A	3
CellulaREvolution	Europe	2019	Supplier	No	0	6
Ourochef	Unknown	2019	Supplier	No	N/A	3
Vivax Bio (part of a larger business)	USA	2018	Supplier	Yes	N/A	7

1: Derivation see Appendix I; 2: Derivation see Appendix H; 3: Derivation see Appendix G.

Appendix G. Methodological Notes on Number of Employees per Company

The number of employees per company was evaluated by a LinkedIn[47] search. For this purpose, the name of the company was inserted in the LinkedIn search. The starting point was GFI's company database (GFI, 2019c), as displayed in Table 0-5. If the company has a company profile, LinkedIn displays the number of employees. Although this figure is surely not perfect because not all employees are on LinkedIn, also non-employees such as board members have it on their profile, I suppose it is a good-enough estimate. If a CM start-up operates more than one line of business – this applied only to WildEarth and JUST, see Table 0-5 – I allocated 10% of their employees on LinkedIn to their CM division. If the company was not found on LinkedIn, I looked how many individuals put the company's name on their personal profile. If also like this no company was found, I allotted the number of founders as listed in the GFI list.

Appendix H. Methodological Notes on Investment per Company

The investment received was evaluated via Crunchbase searches. For this purpose, the name of the company was inserted in the Crunchbase search. The starting point was GFI's company database (GFI, 2019c), as displayed in Table 0-5. If the company has a profile on Crunchbase, a profile appears with the investment they have received. Crunchbase does not cover all investment deals, particularly not those that are made not public. It typically also not covers pre equity investment, i.e. seed or angel investments. After series A – the first venture capital investment a company receives – however, the data should be somehow accurate. The data matches approximately the data by other sources, particularly GFI (2019a) and GFI (2020). Similar to above, if a company is not only focused on CM, I allotted 10% of the investment of that company to CM. Again, that only applied to WildEarth and JUST. If the company was not found on Crunchbase, I conducted an additional Google search on it with keywords such as "(name of the company) investment". If this search was also negative, I allotted zero investment to the company.

Appendix I. Methodological Notes on Focal vs. Supplier Split

The starting point was GFI's company database (GFI, 2019c), as displayed in Table 0-5. If a company was listed to produce explicitly cultured meat, cultured fish etc., it was manually marked as focal company. If the company was listed to produce anything else, for instance growth medium or bioreactors, it was marked as supplier company. If there was an ambiguous entry or any other unclarity, I searched for the company via Google and confirmed what the role in the supply chain the company is trying to fulfil.

Appendix J. Methodological Notes on Location of Top VC Firms invested in CM

The starting point was the data by the GFI (2019a). The following firms were listed to have more than one investment in CM, see Table 0-6. The location of the firms was determined by online search.

Table 0-6: VC Firms with more than one Investment in CM.

VC Firm	Number of Investments	Region
CPT Capital	6	Europe
New Crop Capital	6	USA
Stray Dog Capital	5	USA
SOSV	4	USA
Blue Horizon Ventures	3	Europe
IndieBio	3	USA
VegInvest	3	USA
Fifty Years	2	USA
The Kitchen FoodTech Hub	2	Israel
Tyson Foods	2	USA

[47] Available online at: https://www.linkedin.com/; accessed 29/01/2020

Appendix K. Methodological Notes on New Harvest PhD Scholarships by Region

This search entailed simply counting with which research organisations the past PhD scholarships given by New Harvest were associated, and then allotting these to regions. The total list is accessible online[48].

Appendix L. Methodological Notes on Google Trends Search

The analysis was conducted via Google Trends[49]. Google Trends indicate how often people search via Google for specified search items *relatively to all other search items*. The result is a unitless number that can only be interpreted in comparison to other search items or regions.

Google Trend allows in the regular mode only five search items. I used: “cultured meat”, “cultivated meat”, “lab grown meat”, “in vitro meat”, and “clean meat”, arguably the five most common names for CM. Only data for web searches were used. I downloaded then the results for the analysed five regions. I tried to use translated terms for CM, for instance for Germany. However, these translated terms yielded worse results than the English original terms, so I used the English terms.

Afterwards, the data was downloaded. For the five terms, the sum was calculated, and then an average of that sum by year. The detail date range was from 15/02/2015 (calendar week 7) to 02/02/2020 (calendar week 5).

The European average is weighted by the population of these four countries. Particularly, the weightings that were used are 35% for Germany (population: 82.79m), 29% for France (population: 66.99m), 28% for the United Kingdom (population: 66.44m), and 7% for the Netherlands (population: 17.18m).

Because the naming of CM is still constantly changing and particularly non-English names are typically not yet defined, the results of this analysis should be interpreted with a grain of salt. It can likely give a valid indication of the overall trend, but likely do not give a very robust representation of the public’s awareness in a given country.

Appendix M. Methodological Notes on Consumer Acceptance

The data presented in Figure 5-26 is based on an weighted adjustment of answers to surveys in the USA (Bryant et al., 2019; Surveygoo, 2018; Wilks et al., 2019; Wilks & Phillips, 2017) and for Europe in the United Kingdom (Surveygoo, 2018; YouGov, 2013), the Netherlands (Post, 2014), and Italy (Mancini & Antonioli, 2019). The survey answers to questions pertaining to willingness to try, willingness to buy, and willingness to eat were treated equally. Then the answers were transformed from the typically 7-item or 5-item scale to the 3-item scale visible in the figure. In both cases the midpoint was taken as the “maybe” response in the scale, and the three respectively two positive respectively negative scale points were used to create the new scale points “probably yes” and “probably no”. Then the responses on the new 3-item scale were averaged across all surveys in the sample. Afterwards, for Europe, the responses were weighted by the population of the countries in the sample (United Kingdom: 66.44mio, Italy: 60.48mio., Netherlands: 17.18mio.) to create a composite value.

[48] Accessible online at: https://www.new-harvest.org/past_research_projects; accessed 02/02/2020.
[49] Accessible online at: https://trends.google.de/trends/; accessed 09/02/2020.

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