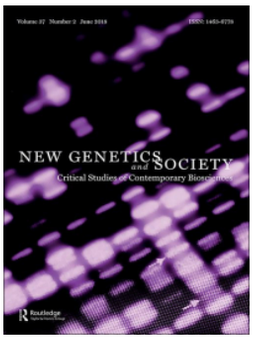

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Capitalization and the production of value at the nexus of academia and industry: the case of a microbiome startup

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This article analyses valuation practices, focusing on the way health data constitute different kinds of assets for different actors within an industry-academia partnership in the field of microbiome research. It examines emerging bioeconomic dynamics within data-driven computational biology, contributing to debates about the sociopolitical implications of multiple and synergic valuation practices in personalized medicine for future public health. Through the ethnographic exploration of a personalized nutrition startup active in Europe and the US and a metagenomics research lab based in Italy, we explore the dynamics around the intersection of knowledge production with scientific, economic, and health value. In contrast to traditional commodity and rent-based structures, we expose a hybrid model of bioeconomic enterprise that challenges rigid distinctions between commodification and asset-based rentiership, highlighting synergic business models where multiple registers of the value of worth are played out, translated, and combined. The study unveils a nuanced relationship between data, research, and economic drivers, where scientists perceive they can pursue research independently from market pressures. Beyond these perceptions and narratives, we highlight the economic dynamics that suture basic research and industry in their promotion of health governance that causes social justice concerns by restricting access to high income and hegemonic types of clients/patients. We clarify that epistemic aspects cannot be disentangled from sociopolitical aspects, especially in the digital age, and that where governments implement and enhance digital health solutions, they also need to plan for consistent social (re)adjustments.

Keywords: Valuation practices; academic capitalism; bioeconomy; microbiome; knowledge production; personalized medicine

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Introduction

> Our scientific research is not driven by the need to increase the value of a product or something they [Foodomics] value. I believe they primarily benefit from our collaboration through the scientific reputation associated with the fact that what they do is the result of scientific research done by reliable external centers like us.
> Filippo, MicroLab.

This article analyses valuation practices, focusing on how health data become different kinds of assets for different actors within an industry-academia partnership in the field of microbiome research. The article examines emerging bioeconomic dynamics within data-driven computational biology, contributing to debates about the sociopolitical implications of multiple and synergic valuation practices in personalized medicine for the future of public health. Filippo, author of the opening quote, is a postdoctoral fellow at MicroLab, an academic research laboratory based in Italy, which pursues metagenomic research on the gut microbiome. The microbiome is the ecosystem of microbes residing on and within the human body (Berg *et al*. 2020); the gut microbiome, in particular, plays a pivotal role in digestion, immune functions, and cardio-metabolic health. I[1] first connected with Filippo online; he discussed the work carried out at MicroLab, considered a hub of excellence for metagenomics in Europe and worldwide. Metagenomic research is the structural and functional analysis of genetic material isolated from all organisms – typically microbes – in bulk samples. This is called "dry" biology, indicating that Filippo and his colleagues work with laptops and algorithms rather than at the bench.

For several years, Filippo, Roberto (MicroLab's PI), and other team members have collaborated with Foodomics. Foodomics is a successful for-profit startup based in Europe and the US; it uses Direct-to-Consumer (DTC) kits and MicroLab's analyses of user microbiomic data to deliver personalized dietary advice to customers through a proprietary app. Foodomics' early success benefited greatly from one of its founders' (Dr. Swim) widespread scientific and public recognition; today, the cooperation with MicroLab furthers this success.

This article analyzes how data is valued in this collaboration and studies the tension between knowledge production and market drives in the context of academic capitalism, where biology has a growing economic value. By reflecting on the broader political economy in which these organizations are situated, we highlight the multiple instances of value (scientific, economic, health) and methods employed for their production as assets. Researchers and organizations are semi-entrepreneurs in the neoliberal market, making profit by converting epistemic into economic value or extracting monetary value from it. However, the expectations and motivations enabling the system are differentiated and complementary: MicroLab's interest is advancing the scientific understanding of the gut microbiome's intersection with human health and developing better health

interventions, while Foodomics aims to generate an economic surplus to fuel its commercial activities and re-invest in further research.

As a result, though working with the same data, MicroLab and Foodomics operate in different markets. The former consists of epistemic value extracted from data, while in the latter products and services are sold as commodities and data become assets to generate economic value. These markets are different but not separate. We will critically analyze the disentanglement of research from economy and show how the synergy between seemingly disinterested knowledge production and market interests increases personalization, not only in medical solutions targeted toward personal biology but also in health governance: funding and research is increasingly biased toward white, middle to high income clients who provide data to increase their wellness.

This provides an opportunity, because easy access to data may translate into high-impact innovations that ideally would benefit a broad spectrum of patients. However, it could normalize a personalized approach to health that risks being exclusive, by making it increasingly difficult for low-income patients in societies without universal healthcare to receive adequate treatment. We delve into the ambiguities and synergies of academia-industry partnerships in personalized medicine, moving beyond scientists' perceptions of their neat complementarity.

In light of these broad sociopolitical implications and because valuation practices are always dependent on social configurations, we acknowledge the need to focus on economic details when ascertaining the motivations and risks of industry-academia collaborations. The literature observes two predominant models – commodity and rent-based – in the production of value within academia. Our research highlights a third, which merges the two cited. The hybridity in this model is not limited to a capitalist market economy; it allows for an alternative, complementary narrative, whereby research and profits coexist and different "grammars of worth" (Morrison 2019) are mobilized, translated, combined, and interwoven in the production of heterogeneous values (epistemic, clinical, and economic).

Our approach extends the notion of "hybrid zones" (Hauskeller and Beltrame 2016) to spaces of practice where distinctions between the public and private sector, redistributive and market economy, and commodification and de-commodification are substituted by overlaps, contaminations, and emerging forms of hybridization. The conceptualization of hybridization in industry-academia relations is not new; nor is the idea that "economic" and "theoretical expectations" can be "related and converted into one another" as they act as "exchange media" in the industry-academia nexus (Etzkowitz and Leydesdorff 2000, 119). While previous studies have mainly focused on institutional changes and the novel role of universities and scientists in the dynamics of innovation (Etzkowitz 1998; Etzkowitz and Leydesdorff 2000), the notion of hybrid zones shifts the focus from institutional arrangements and economic forms to the situated practices producing and combining heterogeneous values within scientific and bio-economic enterprises. It

highlights the valuing practices and conversion of values beneath the hybrid institutional configurations of the industry-academia nexus.

Our studied hybrid zone is relevant due to its distinctive merging of scientific knowledge production and profit-making through a combination of commodification and asset-based accumulation. Moreover, it has important biopolitical consequences, since the economic burden of prevention and promissory healthcare shifts entirely to consumers who can afford to access the research. This raises the question of who can access care in an unequal and vulnerable world: it produces and promotes forms of health governance based on shifting and increasingly individualized biopolitics of responsibility (Lee 2017), prioritizes choice (instead of care) in health governance (Mol 2008), and normalizes the "expert patient" (Briggs and Hallin 2007; Lindsay and Vrijhoef 2009; Rogers 2009).

After recounting the debate on the biopolitics and bioeconomy of microbiome research within academic capitalism, in which assetization practices play a fundamental role, we will draw on empirical data to explore specific dynamics between commodification and assetization that point to the hybrid model and the concurrent values within our case study. This will lead to a critical analysis focusing on individual gains and sociopolitical costs around future health policies.

Methodological framework

We employed a socio-anthropological lens to investigate the dynamics of value production in microbiome research. Ethnographic fieldwork was conducted between October 2022 and June 2023, focusing on the two organizations. Due to the COVID-19 pandemic, most work was confined to virtual interaction, with only one visit to MicroLab's premises. The study involved thematic analysis of available online data, supplemented by semi-structured interviews. These interviews involved laboratory heads, post-doctoral researchers, scholars, and individuals engaged in the user research sector. While our primary focus was the production of multiple forms of knowledge and related values, we acknowledge a limitation in the coverage of consumers. Due to privacy constraints, it was not feasible to contact customers. We independently reached out to customers through social media but received either poor responses or refusal to participate in research.

Traditional fieldwork methods were adapted to accommodate pandemic restrictions. Digital ethnography was utilized to gather qualitative data; interviews were conducted via videoconferencing platforms. The questions were designed to explore participants' roles, the nature of their work, and their perspectives on the collaboration between academia and industry within the microbiome field.

We also collected and analyzed online content relating to MicroLab and Foodomics. This included publications, press releases, social media posts, and website content. These materials provided context and insights into the value production of the two organizations and the way they communicated their work to the public and their stakeholders.

Data analysis was conducted using thematic analysis and grounded theory to identify key themes and patterns in the data. It involved coding the data, identifying recurrent themes, and constructing theoretical frameworks to understand the dynamics of value production for our specific case study. Thematic analysis was used to identify and organize patterns across the data. Grounded theory was employed to develop a theoretical understanding of the processes of commodification and assetization. This involved iterative cycles of data collection and analysis, allowing us to refine emerging concepts and develop a cohesive theoretical framework.

The research followed GDPR guidelines and standard procedures for handling personal data. Ethics approval was granted by the Ethics Committee of Ca' Foscari University of Venice and the European Research Council. Participants provided informed consent and measures were taken to ensure confidentiality and anonymity. We also shared the article with research participants before submission to confirm their consent and collect feedback. Additionally, a template version of the interview is provided as supplementary material to ensure transparency and reproducibility.

The microbiome between biopolitics and bioeconomy

The microbiome is a propitious empirical locus from which to observe the intricate interplay of biopolitics and bioeconomy. Scholars have observed that the growing datafication of human bodies and the microbes they host (Benezra 2016) raises ethico-legal questions (Bader *et al*. 2023; Handsley-Davis *et al*. 2023; van Wichelen 2023). The processes of datafication – necessary to "see" and grasp the microbiome's functioning – and resulting data-driven epistemology enables a different understanding of microbes compared to "traditional" biological knowledge; this is linked to computational, algorithmic factors (Kotliar and Grosglik 2023). The *homo microbis* is necessarily also a *homo algorithmicus*, built on the algorithmic calculations of trillions of microbial and human data points – a being only capable of accessing its non-human parts through self-quantifying consumption, made possible by self-analysis kits or following opaque algorithmic recommendations from an app.

Situated at the nexus of bioscience and biomedicine, microbiome science relates to the translational agenda, personalized medicine, and the growing commodification and financialization of health practices. Philosophically and socially, the microbiome challenges entrenched anthropocentric dichotomies such as health/disease, human/non-human, and body/environment. These ontological and bioeconomic issues are related because the economic value of entities is entwined with their ontoepistemic status (De la Cadena and Blaser 2018; Povinelli 2016) and associated disputes. The ambivalent role of the microbiome and the broader "probiotic turn" – as opposed to the "antibiotic turn" – is analyzed by Lorimer (2017, 2019, 2020) as a specific expression of the Global North's political economies of

biotechnology and biomedicine, which "use life to manage life" (2020, 2), often to the detriment of minoritarian groups outside of this protective bubble. However, as Greenhough *et al*. (2020) points out, microbiome commodification remains largely unexplored or limited to ethical propositions regarding the conduct of research.

There are few exceptions: so far, Widmer (2021) offers the sole example of a study based on empirical research into specific mechanisms of value production and commodification in the microbiome field. Specifically, she analyzes DTC tests as part of the process of commodification and financialization of health practices. In her view, such tests rely solely upon users' paradoxical willingness to pay to carry out (unpaid) reproductive labor in their domestic spaces, from which only the DTC companies benefit economically and in terms of data. Lee (2017) identifies DTC genetics as "a political project that exemplifies how neoliberalism and contemporary transformations in medicine construe disease and its management through economic rationalities" (35), effectively making users both producers and consumers of their own data.

Such considerations have been further developed by van Wichelen's (2023) analysis of the ethico-legal challenges arising from the emerging centrality of bioinformatics. Observing the traffic between precision medicine and global public health, she traces two intersecting but opposed ethical narratives: data are valued for their promissory public good, while the patentability of precision microbiomics is increasing. She notes, "Microbiomic data, then, toggle between competing narratives, of humanitarianism and economy, scientific progress and global inequality, bioprospecting and biopiracy, and data sovereignty and 'open science.'" (389).

Research by Del Savio, Prainsack and Buyx (2017) on the British Gut Project (BGP) highlights the importance of prosocial motivations, such as altruism and solidarity, when recruiting participants for microbiome research. The participants are driven by a desire to contribute to scientific research and public health, rather than personal health benefits. This underscores the significance of framing microbiome research within the context of public benefit and scientific advancement. Del Savio also emphasizes the ethical implications of commodifying personal health data, advocating for data sharing that benefits the broader scientific community. We expand the debate through an empirical account of the production and commodification of *homo microbis* and its possible afterlives through *homo algorithmicus* (Kotliar and Grosglik 2023).

Academic capitalism and assetization processes

The literature has stressed the commodification of the microbiome field. The bioeconomy of microbiome science and its application – and biopolitical implications – must be better characterized within the discussion about academic capitalism (and the industry-academia nexus) in which microbiome research takes place. Meanwhile, to understand better how the microbiome is becoming

economically profitable, the dynamics of commodification and assetization should be unpacked within this field. Thus, we now delve into the concept of academic capitalism and explore how assetization processes shape the production and management of kinds of value within microbiome research.

Microbiome commodification practices exist within the context of "academic capitalism" initiated by the US Bayh-Dole Act (1980). This legislation allows US universities and small businesses to retain ownership of federally-funded research outcomes, fostering a culture of profit-making and capitalism within academic organizations (Aldridge and Audretsch 2011).

Following the parallel that Bourdieu (1975) established between researchers and capitalists, scholars have discussed the entrepreneurial and "quasi-firm" attitude of contemporary science (Etzkowitz 2003; Latour and Woolgar (1979) 2013; Mirowski 2011). The terms "academic capitalism" (Hackett 2014; Slaughter and Leslie 1997; Slaughter and Rhoades 1996) and "entrepreneurial universities" (Etzkowitz 2004) emphasize the increasing involvement of universities and research centers as central actors in the market economy (see also Červinková 2009; Franssen *et al*. 2018).

Muniesa *et al*. (2017), Fochler (2016), and Hackett (2014) have stressed the importance of capitalism as an analytical framework to unravel the processes governing scientific research in universities. However, we must ascertain how to conceptualize capitalism to account for the heterogeneous practices of value production that occur, merge, and overlap within hybrid zones. Studies of new institutional configurations of relationships between academia and industry have already underlined the hybrid nature of these configurations and the exchange and conversion of economic and epistemic values (Etzkowitz and Leydesdorff 2000). Stark (2009) introduced the term "heterarchy" to describe institutional settings wherein multiple evaluative frameworks are maintained and different forms of value are negotiated. Such organizations, he argued, are entrepreneurial in that they profitably navigate competing worth regimes and produce new ways of thinking by "fostering productive frictions" (14) between diverse evaluation models. Our study draws on these notions but also shows how, in hybrid zones, the coexistence of multiple evaluative frameworks and value(s) is produced and managed but not always perceived – as shown in the opening quotation.

In order to move the notion of hybridity from institutional configurations to valuing practices and the conversion and overlap of different regimes and "grammars of worth" (Morrison 2019), we must discuss how the production of value has been conceptualized in social studies of biotechnologies, where the first analytical framework for dealing with the emergence of a bioeconomy (Rose 2001) was developed. Within this literature, the bioeconomic goal of harnessing the reproductive power and promissory nature of biomaterials for profit has been conceptualized as "biovalue" (Waldby 2002) and "biocapital" (Sunder Rajan 2006).

These concepts refer to the way the generative and transformative productivity of living entities can be exploited in the form of commercial bioproducts. The

notion of biocapital has been defined around the "processes of commodification" (Sunder Rajan 2003, 88) and is linked to discussions on academic capitalism and the commercialization of science. Biocapital is "the simultaneous systemic and emergent production of the life sciences … alongside the frameworks of capital and the market" (Sunder Rajan 2007, 80), as life sciences and biomedicine "have all been changing […] toward more corporate forms and context of research" (Sunder Rajan 2006, 4).

Birch and Tyfield (2013) have criticized these approaches for their reliance on the political-economic notions of commodification. They observe that despite often failing to meet market promises regarding new products or services, most life sciences firms are still highly valued. To untangle the issue of value creation and management within the bioeconomy, Birch (2017a, 3) suggests considering the central role played by social practices of valuing – capitalization, assetization, financialization – implemented by relevant politico-economical actors.

Capitalization involves the construction of capital and value through practices such as accounting, standard setting, and market regulations: Muniesa (2017, 40) defines it as "the [discounted] amount a capitalist would be prepared to pay now to receive a higher future flow of money." Financialization emphasizes the role of financial markets and instruments over trade in shaping economic activities. Assetization leverages notions of ownership and exclusivity to conceptualize value in relation to organizational entities (e.g. biotech firms) rather than commodity production (Birch 2017a, 9); it is the process of generating value through ongoing management of value and valuation practices (11).

According to Birch and Tyfield (2013, 302), the notion of an asset-based bioeconomy allows us to outline how bioscientific knowledge and technologies can be capitalized to generate profit; in contrast, focusing on bioproducts as commodities leaves important political-economic processes and practices of valuation "currently unexplored and unacknowledged." Birch further claims (10) that assets' ownership and accumulation dynamics, rather than product or commodity sales, is key to the functioning of value in the bioeconomy. As we will show, an asset-based approach better enables the unpacking of conversion dynamics between different forms of capital, regimes of value, and "grammars of worth" (Morrison 2019). However, to utilize fully the wider exploration of valuing practices in the microbiome sector, we must avoid excessively tightening the commodity-based vs asset-based economy dichotomy. Indeed, in a hybrid zone where multiple values are produced and profit is realized through complex choreographies of commodification and assetization, we can escape the rigid dichotomy between assets and commodities. This requires clarification of these terms.

We use Birch and Muniesa's (2020) definition of "asset" as "something that can be owned or controlled, traded and capitalized as a revenue stream, often involving the valuation of discounted future earnings in the present" (2). Assets, they write, are "often unique, meaning that their value derives from their asset specificity (Teece 1986); as such, it is not possible to reproduce them easily, cheaply, or

even at all" (6). According to Birch and Muniesa, nothing is inherently an asset. Things can *be made into* assets through the specific social practices of valuing in technoscientific capitalism mentioned above – capitalization, financialization, assetization. These practices focus on nurturing, valuing, organizing, and managing resources to transform them into valuable assets. Assets are different from commodities in important ways. Commodities – standardized, tradable, material goods – are produced for exchange on product markets. While commodities generate revenues through sales, assets – owned tangible or intangible resources – generate value through financial and political-economic practices such as intellectual property regimes (IPRs), royalties, licenses, initial public offerings, acquisitions, shares trade, and other financial mechanisms.

We follow the standpoint of Birch and Tyfield (2013) and Birch (2017b) that viewing the bioeconomy through the lens of asset-based mechanisms can elucidate the importance of different practices of valuation – in particular the transformation of scientific knowledge and technological capabilities into assets. However, we elaborate on their claim that, in the life sciences, knowledge, technologies, and derived bioproducts "are ambiguous in that they embody characteristics of a commodity and an asset at the same time" (Birch and Tyfield 2013, 302).

While we adopt their notions of assetization and rent exploitation, we move beyond the focus on political-economic actors and purely financial practices of capitalization, shifting our gaze to other actors and mechanisms of valuation. In doing so, we engage with the broader landscape of data valuation, as illustrated by Fiske *et al*. (2023), who examine how health data creates value through its multiple roles and functions across healthcare contexts. Their typology highlights the performative nature of value creation in health data, and how data journeys (Leonelli 2016) – driven by stakeholder expectations and regulatory frameworks – shape both the epistemic and political dimensions of health data use.

Following Helgesson and Muniesa (2013, 2), who define valuation as "an engaging social practice," we recognize that different knowledge and technological assets are valued according to different "grammars of worth" (Morrison 2019) held by different actors. These multiple valuation practices are combined, translated, and merged to generate different forms of capital (economic, reputational, epistemic) that are similarly combined, translated, and merged. We will show how the datafication of the microbiome involves the assetization and commodification of knowledge, technologies, and raw microbiomic data. This process of commodification can spur the generation of assets and facilitate conversion and translation among them.

We consider the multiplicity of these regimes not merely because hybrid zones are inhabited by heterogeneous actors from different social worlds with different regimes of worth, but also as part of a reflection on academic capitalism. Fochler (2016), in particular, has discussed how academic capitalism should be considered "a particular cultural way of producing, attributing, and accumulating specific forms of worth" (928) that are not necessarily monetary. He identifies numerous

and diverse forms of capital – economic, credibility, reputational – theorizing a capitalist production cycle in which the epistemic capital generated by laboratories becomes a strategic asset used to capitalize on prestige and credibility and thus ensure the conversion of scientific knowledge into economic capital, e.g. by attracting more grants and funding.

This accumulation cycle has been criticized for limiting the conceptualization of value production to just one model – capitalism and capitalization – and hence compressing the analysis of knowledge-making practices (Pinel 2021, 279). The important aspect for our analytical framework is the multi-conversion of various forms of worth, such as the two-way translation of epistemic capital, prestige, and credibility into tangible contracts, licenses, and partnerships with economic actors seeking opportunities for commercial exploitation or (knowledge) asset accumulation. We thus follow Bear *et al*. (2015) and Pinel (2021), who have urged a deeper understanding of capitalism and its diverse forms and motivations through proper ethnography. Inspired by their work, our study is grounded in empirical data; we seek to unpack the dynamics of value production within the lab by closely examining the diverse forms of work, resources, and activities at play and viewing them as "assets." Based on the notions of hybrid zone and conversion of different assets within multiple forms of worth, the next three sections will empirically illustrate how various types of value – scientific, economic, and health – are produced and co-exist through the assetization processes underlying the data traffic between MicroLab and Foodomics.

The role of data in value creation

MicroLab and Foodomics leverage data as a critical resource, transforming them into valuable assets that drive scientific advancements and economic viability. Foodomics navigates the crossroads of profit-driven operations and scientific inquiry within the food and nutrition sector, collecting large amounts of data from customers. Data are the most important and valuable resource for both MicroLab and Foodomics. Foodomics can generate extensive data, which is a competitive advantage in that having more data allows the company to improve and perfect its services and explore new frontiers in microbiome-based personalized nutrition. Access to this data motivated MicroLab to collaborate with Foodomics; raw microbiomic data are the prime resource for the lab's metagenomic analysis and hence of crucial importance.

MicroLab is a hub of innovation in the field of metagenomics, converting resources into valuable assets. Roberto, having worked at Harvard on the NIH project "Human Microbiome," returned to Europe and cultivated a robust international standing in the realms of metagenomics and exploration of the human microbiome. This is a cornerstone of the lab's prestige and credibility in international forums; it is a result of various factors, including the innovative nature of their research and the identification of previously undiscovered microbial strains.

Leveraging this expertise and knowledge, MicroLab transforms scientific outputs into publications and IT tools such as software, workflows, and pipelines for microbiome research. This not only generates epistemic value by advancing the understanding of the microbiome's interactions with health, but also enhances the lab's prestige and solidifies its standing within the scientific community, fostering new collaborations and projects. Through social engagement with external actors and curation of resources, MicroLab bolsters its reputational capital, enabling open access to resources and advances in research.

Despite their shared interest in data, the two organizations seek different results from their assetization. MicroLab's aim is essentially to pursue basic research on the gut microbiome's composition, functioning, and connections with health. Matteo, one of MicroLab's members, explained:

> […] there is a general interest for the "cardio-metabolic health, diet and microbiome" line of research within the lab; Foodomics supplies the lab with lots of data, but this doesn't mean that our research is directed towards augmenting the value of their service. […] We do our research, and if something that might interest them comes out, *then* we talk about it.
>
> Matteo, MicroLab (original emphasis)

Meanwhile, the startup nature of Foodomics suggests that it values basic research – and the resulting epistemic values – from a different angle. Foodomics' mission is to transform data into marketable assets that generate economic value. This exemplifies what we previously called choreographies of commodification and assetization. Data result from the sale of DTCs (a *commodity*), but when elaborated and transformed into an *asset*, they become a resource that provides individual microbiomic and metabolic profiling and delivery of tailored dietary programs through the app (a *commodity* in the form of a service). The more the commodity is sold, the more data are collected and analyzed (providing knowledge assets) and the better the service provided, which in turn increases the market attractiveness of both the product (DTC kit) and service (app and dietary program).

This is a case of hybridity between the commodity and asset status; as highlighted by Birch and Tyfield (2013), an asset's value increases along with demand, while the opposite happens with a commodity. Here, the effect of the microbiome's datafication is that as the value of the asset increases, so does the value of the commodity. While this dynamic is not new with regard to DTC genetic products and services (e.g. Harris, Wyatt, and Kelly 2013; Tutton and Prainsack 2011), this specific hybrid zone introduces two original elements: assetization and marketization of personalization; and collaboration with external non-profit actors (see following sections).

Regarding personalization, the co-operation with MicroLab and its technology and knowledge – combined with data from the app – enables Foodomics to deliver tailored dietary programs to users, ultimately driving economic viability while simultaneously advancing scientific understanding. Foodomics' approach to

personalization is not confined to the biological; rather, as emphasized by their lead nutritional scientist Stella, it adopts a 360° approach showing the true complexity of the concept:

> […] we believe that personalization doesn't just stop with individualized metabolic analyses. *True* personalization also involves how people live their lives, their character, cultural traditions, personality, daily habits and even religious practices. And that is what we're trying to do here.
>
> Stella, Foodomics (original emphasis)

Foodomics is prepared to compensate external hubs such as MicroLab to clean their data (removing superficial information) and dig valuable insights out of what Stella calls the "goldmine of data" at their disposal. This process, called "data curation," is pivotal in transforming Foodomics' raw microbiomic data into assets, as it underscores their potential and enhances reuse and interoperability. These are important characteristics for working with open science frameworks such as the FAIR principles (Wilkinson *et al*. 2016) and for the commercialization of data. In this way, personalization, through datafication, becomes an asset for advancing scientific understanding (i.e. scientific capital), offering a lucrative biological service to customers (i.e. economic capital), and gaining symbolic capital from collaboration with a public research organization and compliance with open science frameworks.

The pivotal role of raw microbiome data emerges as a linchpin in this narrative. The ability to preserve, access, and reevaluate this data, even years later, aligns with the dynamic and evolving nature of microbiome science and its economic and commercial exploitability. However, it cannot overshadow the social and biopolitical implications. The fact that companies typically do not grant users direct access to their data is critical. These data might have significant implications for individuals, yet most companies in the sector only share with their users a summary of the insights gained from their analyses. This prompts reflection on broader issues of accessibility, monopolization, and the evolving capacity of individuals to engage with their own health data amidst the dynamism of technoscientific progress.

Moving assets, producing value(s)

As described above, the cooperation between Foodomics and MicroLab is aimed at mobilizing different forms of capital and generating value from data. In this section, we focus on the specific strategies for leveraging proprietary assets involving different valuation practices. We observe two primary methods employed by scientists to generate value(s) from proprietary assets.

First, laboratories *create* value by internally mobilizing technical and knowledge assets that can later become marketable products or services (e.g. Foodomics' DTC tests and dietary programs) or be exchanged for credibility tokens (e.g. MicroLab's IT tools and relevant publications) – valuable for accessing research

grants and enhancing reputation in relevant circles. The conversion of credibility tokens into research funds closes the loop, enabling laboratories to transform available epistemic capital into economic capital, which is later reinvested in research. Symmetrically, the company creates value not only by selling marketable products or services but also by making their data available to public research organizations. This cooperation increases the value of their data and converts the collaboration into symbolic capital, enhancing the company's value, the market attractiveness of its products and services, and its corporate and market reputation.

We observed a complex, bilateral transformation of economic, epistemic, and social capital, along with related resources, assets, and commodities, into valuable assets that cross the borders of two different value production systems and political-economic regimes. While these assets move across economies, following the flow of microbiome data, actors can maintain the institutional identity of their professional culture and their goals within their respective economies. For example, Andrea (MicroLab) describes the work of his organization thus:

> Our [MicroLab's] research is mainly data-driven. […] If we happen to identify interesting signals from the data we analyze, we delve deeper. […] This also applies to Foodomics' data: we are independent in our research, and if something we find ends up being beneficial to Foodomics, that is a by-product of our research, not its main goal.
>
> Andrea, MicroLab

While MicroLab benefits from the data provided by Foodomics and endows them with marketable value, Andrea uses what Morrison (2019, 50) calls a "grammar of worth": he maintains an institutional separation, allowing MicroLab to perceive itself as abstracted from economic or other dynamics. In this hybrid zone, data move and generate valuable research results that can be commodified, assetized, and negotiated with external actors such as academic journals, prospective patients, or Foodomics' own clients.

The second method of value production is the valuation of ownership of a monopolized asset. Here, value is *extracted* from political-economic practices such as IPRs, royalties, patents and licenses, deriving a continuous flow of revenue from selling assets to external actors (Birch 2020; Fields 2022; Frase 2016). This method is closer to what Birch and Muniesa (2020), Muniesa *et al*. (2017), Birch and Tyfield (2013), Beltrame (2019), and Pinel (2021) call the "rentier model of value production and accumulation" active in the bioeconomy. Here, the continuous accumulation of unique and valuable proprietary assets, managed exclusively by an organization, allows for passive extraction of monetary and reputational value through rents – which are contingent upon the rented asset's credibility and prestige within relevant circles. Within the bioeconomy of microbiome research, the versatility, mobility, uniqueness, and specificity of data appears to fit optimally within this model (Beauvisage and Mellet 2020; Frase 2016; Geiger and Gross 2021; Sadowski 2019).

However, our case study is unique in that Foodomics does not extract monetary value (through rents) from commercial partners such as MicroLab, but instead from its customers through a monthly subscription fee. External collaborations do not generate a revenue stream as predicted by the rentier model described above; in fact, the collaboration with MicroLab requires expenditure, which Foodomics is able to recoup from its clients.

We have discussed how the elaboration of data by MicroLab increases the value of Foodomics' products, services, and symbolic capital (translated into corporate reputation and market attractiveness). Here, we will emphasize how the valuation of assets involves commodification in the form of Foodomics' personalized nutrition app. This is the material device that allows the company to turn valuable data (collected through another commodity, the DTC kit) into marketable services. Working within rentiership dynamics, the app allows the company to capitalize on the monopoly it has over specific scientific knowledge (gut science) and its derived assets (microbiomic data), engaging in a hybrid form of value(s) production that operates at the intersection of asset-commodification and rent-based extraction.

The promissory nature of microbiome research inflects these dynamics, hindering a straightforward separation between short-term and long-term business plans. The app is simultaneously a commodity generating economic surplus in the present; a technical device accumulating data as assets to increase the future value of the service and provide resources for the development of microbiome science; and a legal device (in the form of membership) to extract rent and facilitate the further accumulation of data. The economic value produced by Foodomics through this hybrid and collaborative form of value production is invested in further research, generating economic surplus in the present – and, it is hoped, the future – through various forms of conversion between capitals and complex articulations of commodities and assets.

Reaching outwards: establishing a community of customers and collaborators

We have described above how Foodomics engages its community of customers. We will now examine the social practices through which it employs customer engagement and strategic partnerships to enhance its data assets and drive innovation within the microbiome sector.

Foodomics adopts a multifaceted approach in order to engage and foster membership within its community, spearheaded by its active scientific presence in the public sphere. Scientifically sound, informative, and accessible articles on food and health are regularly published on its website. These papers are publicly available, with members receiving additional exclusive content. The company also provides a newsletter with nutrition tips from scientists, as well as a "Science and Nutrition" podcast hosted by the Foodomics CEO, which provides an accessible

roundup of health, nutrition, and gut health research. A comprehensive library of all episodes (∼100) is available for free on the company's website and major streaming platforms.

Foodomics also employs various communication strategies to incentivize membership. These include a refer-a-friend program for a free one-month subscription, a continuously updated FAQ section, and full transparency regarding the company's ongoing research and results. Members can also access exclusive sessions with nutrition coaches and user satisfaction personnel. These strategies mobilize scientific legitimacy and symbolic capital, promoting social embeddedness (i.e. social capital) to increase market attractiveness. This is mobilized to attract customers and thus increase the amount of data collected, raising the value of the company's assets.

Strong, long-lasting strategic partnerships also play a central role in the value of Foodomics' data assets and innovation within the microbiome sector. Collaborations with external organizations and institutions such as MicroLab enrich Foodomics' database, generating both scientific and economic value. This is crucial because the amount and quality of data plays a pivotal role. As Filippo explained, microbiome science is still in its infancy: scientific understanding is still limited and causal links between gut microbes and bodily responses (in metabolism and disease control) have not been univocally established. Instead, scientists are making assumptions based on empirical observations linking the microbiome to the body – keeping in mind that "correlation is not causation."

This implies that mobilizing data to produce value is not solely grounded in immediate results or short-term economic return. Instead, microbiome science and the microbiome industry rely on experimentation, hope, and potential future applications of assets. From this perspective, the microbiome sector perfectly epitomizes the speculative nature of the asset, the value of which is inherently tied to its promise – but not necessarily its guarantee – of future capital (Martin 2015; Muniesa 2017). This future-oriented dimension is additional to the ongoing extraction of value from present assets. Foodomics' scientists deliberately engage in experimental practices to nurture the value of their company's data from a future perspective. Meanwhile, the juxtaposition of economic viability and interest in basic research allows the startup to utilize external (and complementary) realities such as that of MicroLab.

When choosing its partners, Foodomics manages the value of its data by regulating who can access its assets and to what extent. This is an important step in the data assetization process, as it enhances data exclusivity and uniqueness. Partnerships are brokered to establish, in Filippo's words, "mutually beneficial relationships that constitute an advantage for both parties: we [MicroLab] get to analyze lots of data, which we wouldn't be able to access otherwise […]; and they [Foodomics] get to benefit from some of the results." A practical example was given by another MicroLab member, Alberto:

> In the past four years we went from working with roughly 1,000 people's data to 25,000/30,000. On top of that we now have new tools that allow our analysis to be much more precise. […] In practice, this meant that we had to revise some of our initial findings to account for the new results. […] Microbiome science is still imprecise and evolving, and the amount of data one can work it makes a very big difference.
>
> Alberto, MicroLab

An article on the innovative IT tools used for MicroLab's analyses, following the lab's new discoveries, provided significant returns for both MicroLab and Foodomics. MicroLab successfully employed its scientific expertise and credibility capital to generate epistemic value, from which it gained reputation and prestige by distributing its research outcomes into the marketplace of ideas (Mirowski 2011), e.g. academic journals. Meanwhile, Foodomics harnessed the economic and visibility potential of MicroLab's latest findings by improving the company's services and benefiting from the exposure granted by the article.

Foodomics' long-term investment thus bore fruit in both economic and reputational terms, as it allowed the company to improve its service by developing more accurate information for its users while also obtaining visibility through MicroLab's article. Moreover, MicroLab can employ technological improvement in the future to analyze a variety of biological processes, including health-related issues with higher stakes than personalized nutrition, such as cancer. This pinpoints the symbiotic relationship between economic investments and scientific advancements. Foodomics' collaborations with external entities involve costs, but also substantial rewards in terms of both economic gains and an enriched scientific repertoire.

The biopolitics of multiple valuation practices and their implications

The previous sections have explored the dynamics and conversions between different grammars of worth, forms of capital, commodities, and assets. We will now address social and biopolitical implications that should be acknowledged in the analysis alongside bioeconomic dynamics.

Pinel (2021) has argued that multiple evaluative frameworks[2] often intersect in academic scientific research, influencing the behavior of the scientists operating within them. She highlights the growing centrality occupied by marketable research results in the field of metagenomics; this risks a situation where the potential for publishable epistemic value could dictate laboratory research lines.

Andrea's words above show how, despite collaborating with a for-profit startup, MicroLab defends its commitment to the advancement of science and downplays the risk of influence from market logic. This defense of academic legitimacy not only highlights the synergies between MicroLab and Foodomics as entities operating within separate political economies; it also attributes to Foodomics a grammar of worth that is more legitimate within the political economy of basic science. Giorgio (MicroLab) described Foodomics' strategy:

> I honestly don't think that they [Foodomics] sell that much in regard to microbiome results. After all, it's still a very niche topic. This allows our scientific research not to be driven by the need to increment the value of a specific product or something that *they* value. […] On top of that, I believe they are genuinely interested in selling something that is backed up by solid science, and are willing to invest a lot of what they make on that. […] That is also why, since the very beginning, they positioned themselves as a company that looks to the world of research as an ally, without snubbing it.
>
> Giorgio, MicroLab

Similarly to Andrea, who described MicroLab's research as "data-driven" (where the data indicate whether something is epistemically interesting) and Foodomics' economic benefit as "a by-product," Giorgio dismisses any influence of market logic by attributing to Foodomics an interest in collaborating with the "world of research" to produce solid science. The synergistic cooperation between the two entities leads to the generation of epistemic and health value, but this does not preclude economic logic. We have described a value-production cycle that enhances the value of Foodomics' data (gathered through the startup's app) through MicroLab's metagenomics analyses. This boosts the app's ability to attract new customers, further increasing the value of Foodomics' data-assets. Reinvestment in research, while advancing knowledge, also perpetuates this cycle and increases the company's value.

Above, we have only discussed the different evaluations of microbiome data in terms of the main stakes for the two political economies of basic science and market economy, emphasizing various hybridizations, conversions, and translations. We will now address the implications of the hybrid zone between academia and industry in terms of health governance. Fiske *et al*. (2023), noting that in the data-driven age different actors often assign different valuations to data, have developed a typology matrix indicating the various functions served by health data and the types of values emerging from them. This matrix examines the roles of health data, the forms of value they create, and the actors for whom they are created.

The matrix bridges the conventional concern about "kinds of data" (more or less risky and sensitive) with the evaluation of the work performed; the authors argue that "regulation should pay more attention to the practice, context, and purpose of use of datasets" and ask "what value is achieved by using a specific set of health data and by whom?" (2023, 492). They advocate for the regulation of data use based on public interest, emphasizing that the anticipation of future health gains "is not enough to decide whether a specific instance of data use is in the public interest" (493). Anticipation is too general, risking data being used in ways that do not enable social justice.

In our case study, which stands at the nexus of academia and industry and is characterized by close collaboration and mutual exchange of expertise, it is hard to disentangle the types of data use and even harder to downplay anticipation as

relevant to the public interest. The data collected by Foodomics are useful for elite patients who use the app to enhance their wellness; however, through MicroLab's work, these data could benefit a broader spectrum of patients and situations, including precision medicine, early detection cancer tests, and targeted solutions for life-threatening conditions. This would contribute to broader health and societal gains.

However, it is important to continue to discuss and ponder what anticipation means: through which data and for whom. It is undeniable that MicroLab's valuation practices are enmeshed – even if indirectly – in market-driven concerns, beyond the scientists' perception. Despite their different tasks and aims, they share involvement in a biopolitics of healthcare commodification aimed at elite patients. MicroLab scientists contribute to this indirectly; the hybrid zone encompassing their collaboration with Foodomics does not constitute protection from market involvement but rather an under-the-radar trigger for it.

The synergistic dynamics between basic science and profit depend on the existence and cultivation of clients who are satisfied with the promissory nature of microbiome research and willing to accommodate its uncertainties. By supporting personalized, elite nutrition, these clients contribute to a "postgenomic condition" in which, as Reardon (2017) argues, future health disparities between rich and poor and between the Global North and South will eventually be exacerbated. She observes that "as in the world of fashion, tailoring is an expensive affair that does not include us all. […] Prices in the tens of thousands of dollars per year will become the norm, with certain drugs commanding six figures per year" (2017, 189). She asks, "Should a mode of doing research so dependent on speed, technological innovation, and venture capital dominate the life sciences? Should a field that promised future – not immediate – improvements in health care move to the heart of biomedicine?" (2017, 186).

Governments in many Western countries are advancing digital health infrastructures of research and e-care in collaboration with industry actors, aiming to enhance the effectiveness of health interventions and to reduce costs (Galasso 2024; Hoeyer 2019; Lievevrouw, Marelli, and Van Hoyweghen 2022). These programs call on the entire population, including historically marginalized and vulnerable groups, to contribute health data. However, there are questions regarding who will truly benefit from these findings and solutions (Fox 2020). Doubts and paradoxes emerge when a push for inclusive data collection is not matched by inclusive access to healthcare (Galasso 2024); this constitutes a pressing social justice issue (Green, Prainsack, and Sabatello 2023; Shaw and Sekalala 2023).

Conclusion

We have studied an industry-academia partnership in the field of microbiome science to reflect on the multiple valuation practices increasingly common in the field of digital health. While others have shown how research in precision

medicine extends into the clinic (Cambrosio *et al*. 2018; Nelson *et al*. 2014), blurring the distinction between the two, we have demonstrated how precision medicine also extends into economic and financialization dynamics, similarly and increasingly blurring the fields of "bios" and economy. To examine the sociopolitical implications of this trend, we focused on the poorly investigated dynamics of collaboration between industry and academia from an economic and technical perspective.

We have shown that, in the two organizations studied, value production entails the meticulous construction, management, and upkeep of valuable resources, some of which become assets. These assets are strategically mobilized to generate diverse forms of value, including epistemic, health, and monetary value. There are two primary models for achieving this goal: commodity- and rent-based extraction. In contrast to models where data assets are leased to research organizations for economic profit (Pinel 2021), Foodomics extracts economic value from its platform's users – though it still benefits from reputational gain associated with MicroLab's discoveries. Foodomics' interest in basic research is coupled with external collaborations to ensure the generation of epistemic value, which, in turn, guarantees the extraction of economic value through service improvements and public outreach.

The epistemic, socio-relational, and marketing practices implemented by MicroLab and Foodomics are crucial in establishing and maintaining full control over their assets, leveraging exclusivity to design products or extract rent and thus creating epistemic, economic, and health value. This reinforces previous observations (Birch, Muniesa, and 2020; Pinel 2021) regarding the intimate connection between value production and assetization processes in the bioeconomy sector. The hybrid model of value production, based on mutual cooperation and different end goals, is perceived by scientists as a way to continue pursuing basic research within industry collaborations. However, we have shown how these dynamics of collaboration require careful scrutiny, as they raise important and urgent questions regarding biopolitics and social justice.

The economic dynamics in our case study show that partnerships between academia and for-profit companies are neither simply nor uniquely driven by capital as traditionally meant in terms of monetary value. Such partnerships develop along an articulation of profit, reputation, investment in further research and instruments, the need to train IT tools to refine and improve their functioning, and the desire to advance basic science. These not only coexist but are fundamental and complementary. However, the perceived autonomy in basic research, the advancement of microbiome knowledge, and the anticipated health benefits do not address the complex ethical and sociopolitical questions involved. In exploring this hybrid zone, we have focused on the Foodomics app: a device that enables conversion from asset to commodity and facilitates collection of large amounts of data for the benefit of microbiome research. However, the app shifts health responsibilities and rights to the consumer-patient, raising questions about the forms of health management that are being popularized and supported.

There is an increasing call for more ethical and responsible research and a better understanding of the social impact of science. To generate meaningful and useful insights, we – as critical observers of commodification dynamics pertaining to the microbiome – have abstained from focusing on the motivations and perspectives voiced by scientists. Rather, we embarked on the harder task of empirically dissecting and unpacking the economic practices on which the academia-industry nexus relies. Microbiome research is taken as a symptom and sign of mutating visions of nature in an increasingly computational world. As such, it is imbued with a social, cultural, and historical specificity, demanding careful scrutiny and triangulation with analysis of various practices; we have examined economic factors and delved into their complexity. Understanding the dynamics of bioeconomy is pivotal; as Helmreich noted, scientists' perceptions are important and often genuine but "they are not the whole story" (2001, 14). This is especially true in a world where public and private, academia and industry, global and local, material and virtual, promise and cure, common good and private profit mix in ways that are sometimes hard to identify and disentangle from a specific perspective. In our attempt to understand how bioeconomy, political economy, and biopolitics enfold at the academia-industry nexus in this specific field of digital health, we neither call for an end to this kind of research nor downplay the importance of basic research and the potential value of anticipation. Rather, we clarify that epistemic aspects cannot be disentangled from sociopolitical aspects, especially in the digital age, and that where governments implement and enhance digital health solutions, they must also plan for consistent social (re)adjustments.

Notes

1. Use of the first singular person refers to the first author, who conducted the ethnography.
2. The term "evaluative frameworks" refers to a collection of evaluative principles implemented through a range of metrics within which actors can legitimately claim different kinds of worth (Pinel 2021, 277; Fochler, Felt, and Müller 2016, 179).

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